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From the Editor
Doug Hendricks, KI6DS

You will note a couple of things about this issue. One there aren't as many pages as usual, and two, I have gone back to 10 point type and 2 columns. Why? Because of the increase in printing costs. To keep the costs down to where we can afford to print andmail QRPp without raising the subscription rates, we have had to do this. I did the issue in the old way, 12 point type and 66 pages, and guess what, there is actually more information in this one than in the old way of doing things.

You will also note that this is a double issue. Everyone who has an expiration date of Winter 2002 will also get the Spring 2003 issue in the same mailing. We ask that you please renew by sending in $15 US and Canday (US Funds of course) and $20 DX to:

Jim Cates
3241 Eastwood Rd.
Sacramento, CA 95841

Please mark your check renewal as that helps Jim and Paul Maciel immensely. Note that your renewal will start with the Spring 2003 issue.

Jim and I both want to thank you for all of your support and we appreciate all that you do for QRP by participating. Have a good year and we hope to see you in person at a QRP Forum or on the air. 72, Doug, KI6DS

The Handiman's Guide to

MOSFET "Switched Mode" Amplifiers

Part 1

Introduction to Class C,D,E and F

by Paul Harden, NA5N

***Part 1** is a tutorial for using switching MOSFET's for QRP power amplifiers. Beginning with the standard Class C power amplifier, special emphasis is given to the Class D, E and F high efficiency modes.*

Meet the MOSFET

MOSFET's have been used for years in QRP transmitters, but with an apparent level of mysticism as to how they really work. There are two main types of mosfet's: the linear RF mosfets, such as Motorola's "RF Line," and the more common switching mosfets. The **RF mosfets** are excellent, reliable devices for up to 30MHz, and some VHF versions. However, they cost $25–35 each or more, and beyond the budgets of most amateurs. **Switching mosfets** are far more common, such as the IRF510, available at hobby vendors and Radio Shack for about $1. These cheap switching mosfet's are the ones used in most home brew QRP transmitters, and the ones upon which this article focuses.

As the name implies, this family of mosfet's are designed to be *switches* – that is, to primarily turn current on or off, just like a switch or relay. They are not perfect. Between the OFF and ON states, there is a linear region. Compared to standard bipolar transistors, mosfets have a narrower linear region. IRF510s, used for QRP Class C PA's, attempt to bias for this more restrictive linear region. However, if the device is accidentally driven into saturation, it causes excessive drain current and heating of the mosfet – and often failure. If you haven't blown up an IRF510 yet – you just haven't worked very hard at it!

The IRF series of switching mosfets were developed by International Rectifier.. They make the "dies" for these mosfet's, marketing them under their own name (logo "I-R"), or selling the dies to other manufacturer's, such as Motorola and Harris, who merely adds the TO-220 packaging. Thus, no matter where you get your IRF510, you are getting the same device and can be assured of consistent operation.

The exception to this are some IRF510s sold by Radio Shack. Some are manufactured in Haiti that may or may not meet specs for maximum drain current, or at what gate voltage the device turns on and reaches saturation. To avoid legal problems with I-R, Radio Shack packages these mosfet "clones" under the part number IFR510 (not IRF510). An unrecognizable logo indicates a device manufactured off-shore.

Most power mosfets are made by stacking several dies in parallel to handle higher currents. The disadvantage is the capacitances add in parallel, which is why power mosfets have large input and output capacitances over single die devices. Mosfets made by vertically stacking the dies are called VMOS, TMOS, HexFets and other such names.

According to the I-R applications engineer, the IRF510 is their most widely sold mosfet. This is because it was developed by I-R in the 1970's for the automotive industry as turn-signal blinkers and headlight dimmers to replace the expensive electro-mechanical switches and relays. The good news is, this implies they will not be going away any time soon. In talking to International Rectifier, they were floored to find out QRPers were using them at 7MHz or higher. I faxed them some QRP circuits to prove it. Quite a difference compared to the 1Hz blink of a turn signal, or the 50kHz rate of a switching power supply!

BJT's vs. MOSFET's

Bipolar junction transistors (BJT) are forward biased with a base voltage about 0.7v (0.6v on most power transistors). Below 0.7v, the transistor is in *cut-off*: no collector current is flowing. Above 0.7v, collector current begins to flow. As you increase the base voltage (which is actually increasing base current), it produces an increase in collector current. This is the *linear region* – converting a small change on the base to a much larger change on the collector. This defines amplification. As you continue to increase the base voltage further, a point will be reached where no further increase in collector current will occur. This is the point of *saturation*, and the point of maximum collector current. The base voltage required to saturate the transistor varies from device to device, but typically falls in the 8v range for most power transistors used for QRP PA's. This is, actually, a fairly large dynamic range. A graph showing these regions is called the "transfer characteristics" of a device, as illustrated in **Fig. 1A**, showing a sample Class C input and output signal. Self-biasing is assumed, that is, the input signal is capacitively coupled to the base with no external (0v) bias.

MOSFETs work in a very similar manner, except the gate voltages that defines cut-off, the linear region, and saturation are different than BJT's.

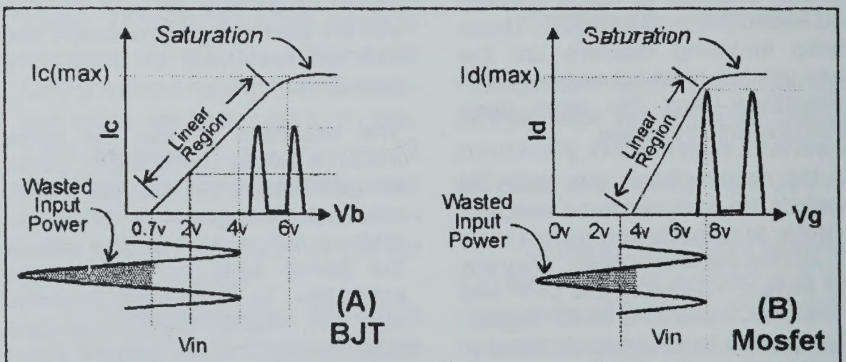


FIG. 1 – Class C Transfer Curves for (A) NPN bipolar transistor (self-biased) and (B) IRF510 mosfet at 3v gate bias

While it takes about 0.7v to turn on a BJT, it takes about 4v to turn on an IRF510 mosfet. The voltage required to cause drain current to start flowing is called the *gate threshold voltage*, or Vgs(th). From the IRF510 data sheet, the Vgs(th) is specified at 3.0v minimum to over 4.0v maximum. This large range is typical of mosfets, whose parameters tend to be quite sloppy compared to BJT's – something to always keep in mind. My experience shows the Vgs(th) of the IRF510 is more in the 3.7-4.0v range and goes into full saturation with about 8v on the gate. This defines a smaller dynamic range (4v–8v) for the linear region than a BJT (0.7v–8v).

The transfer characteristics of a typical IRF510 is shown in **Fig. 1B**. The gate is externally biased at 3v (no-signal) and the input signal is limited to no more than 7v on the peaks to avoid the saturation region. Note that the scaling between the BJT and mosfet transfer curves are different.

Class C PA with a BJT

Figure 2 is a typical schematic of a QRP transmitter PA using an NPN power transistor. RF input from the driver stage is stepped-down through T1 to match the very low input impedance of Q1, typically 10Ω or less. The low output impedance (12–14Ω at 5W) is converted to about 50Ω by the 1:4 step-up transformer T2. This circuit is the common *self-biasing* circuit -- there is no external dc biasing applied to the base, such that the signal voltage alone forward biases the transistor. Referring back to **Fig. 1A**, the shaded area of the input signal shows the power that is wasted in a typical Class C PA using self-biasing. This is power from the driver that *is not being used to produce output power*. This is an inherent short coming of the Class B and C amplifiers.

Class C PA with a MOSFET (IRF510)

The circuit of a typical mosfet **Class C** PA is shown in **Figure 3**. It appears very similar to the BJT circuit in **Fig. 2** in most regards. The RF input signal from the driver stage can be capacitively coupled, as shown, or transformer coupled. Capacitive coupling is easier for applying the external biasing. Since the Vgs(th) of an IRF510 is about 3.5–4.0v, setting of the gate bias, via RV1, should initially be set to about 3v to ensure there is *no drain current with no input*

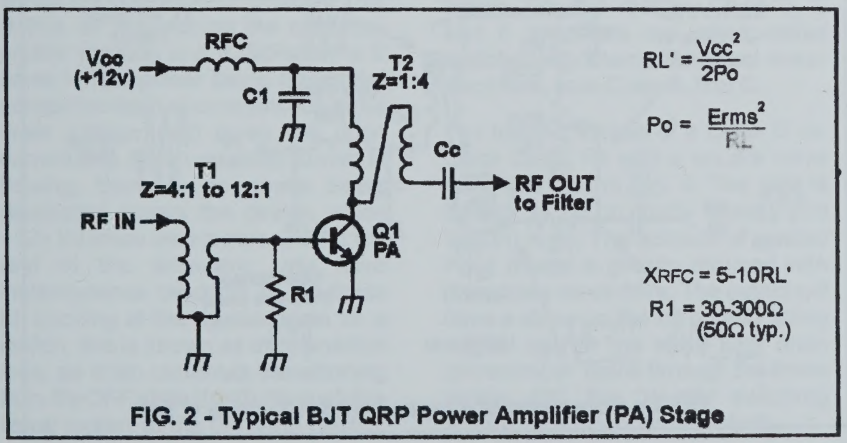


FIG. 2 - Typical BJT QRP Power Amplifier (PA) Stage

signal. R1 is chosen to simply limit RV1 from accidently exceeding 8v on the gate, which would cause maximum drain current to flow and certain destruction after 10–15 seconds. The input RF applied to the gate (during transmit) should likewise never be allowed to exceed about 7–7.5v, just shy of the saturation region. As illustrated, the input signal is 8Vpp, or -4v to +4v after C1, and after the +3v biasing, from –1v to +7v. *This ensures the IRF510 is operating within it's safe operating area* for a Class C amplifier. Like the BJT Class C PA, the input signal from +4v to –1v is wasted power, not being converted to output power.

For a typical Class C PA operating at around 50% efficiency, about 850mA of drain current will be required to produce 5W output. It is wise to monitor the drain current to ensure excessive current is not being drawn, indicating the RF input peaks are approaching the saturation region of the device, or the static gate voltage from RV1 is set too high. This is extremely important to preserve your IRF510 longer than a few moments!

Drain current will only flow when the gate voltage exceeds the Vgs(th) of the device. With a resistive drain load, this translates into +12v of drain voltage when no current is flowing, then dropping towards 0v as drain current flows, as shown in **Fig. 3**. However, with the inductive load of T1, the voltage swing will be 2Vcc (24v) as expected. This is due to the current stored in the inductance of T1 being dumped into the load (low pass filter) when drain current from the IRF510 stops, and is stepped up further, by a factor of two, to about 48Vpp, by the bifilar windings on T1. Some loss through the low pass filter yields about 45Vpp for 5W output.

Once the circuit is working properly, RV1 can be carefully adjusted to produce more power, again carefully monitoring for <1A of current flow. This is much easier to do with an oscilloscope, to ensure that the gate voltage never approaches the 7.5–8v saturation region on the RF peaks, and for a fairly clean sinewave entering the low pass filter.

Evaluating Class C MOSFET Efficiency

A well biased IRF510 PA can be a bit

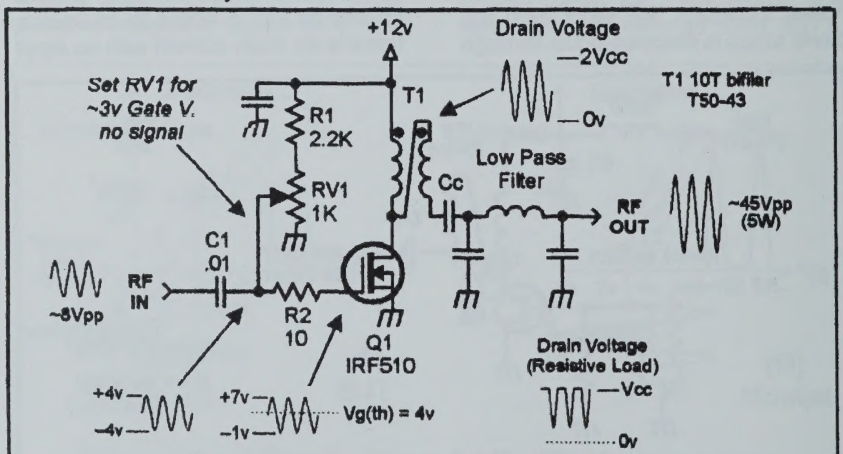


FIG 3 – Schematic of a typical MOSFET Class C PA

more efficient than a BJT circuit, primarily because it takes less peak-peak input signal to produce 5W, and thus less driver power is needed. Since the slope of the linear region is steeper than a BJT, the IRF510 actually has more potential gain.

The largest contributors to power losses, and hence poor efficiency with switching mosfets, are the very large values of input and output capacitances compared to a BJT.

Remember how you've always heard the input impedance of a mosfet is very high, in the megohms? Well, forget you ever heard that! That is the *DC input resistance* of the gate with *no drain current flowing.* The AC input impedance is the Xc of Cin (about 120–180pF) or 130Ω at 40M. This means your driver stage must be able to provide an 8Vpp signal into a 130Ω load, or about *a half watt of drive.*

On the output side, the large output capacitance, *Cout*, is like having a 120pF capacitor from the drain to ground. This absorbs a fair amount of power being generated by the mosfet. But there is nothing you can do about that (at least in Class C).

The other large contributor to reducing efficiency is the power lost across the drain-source junction. This is true as well across the collector-emitter junction in a BJT. Power is E times I. The power being dissipated across the drain-source junction is the drain voltage (Vd) times the drain current (Id). When no drain current is flowing, there is no power being dissipated across the device, since +12v Vd times zero is zero. But for the rest of the sinewave, you have instantaneous products of Vd times Id. Looking at the mosfet again as a switch, this is known as the *transition loss,* as drain current is transitioning from it's OFF state (Id=0), through the linear region, to the ON state (Vd=0).

Of course with Class C, you are in the transition loss region at all times while drain current is flowing. Again, there is little you can do about this loss in Class C amplifiers.

Improving Efficiency (Introduction to Class D/E/F)

From the above, it appears there are three major sources of power loss, leading to poor amplifier efficiency:

1) Transition (switching) losses (Vd x Id products)

2) Large internal gate input capacitance (~120-180pF for the IRF510)

3) Large internal drain-source capacitance (~ 120pF for the IRF510)

If these losses could be largely overcome, then the amplifier's efficiency could be greatly improved.

In class D/E/F, the mosfet is intentionally driven into saturation using a square wave. This drives the mosfet from OFF (Id=0), to fully ON (Vd=0) as quick as possible. The square wave input will have to go to ≥+8v to ensure saturation.

This purposely avoids the linear region, operating the device only as a switch. For this reason, Class D, E and F amplifiers are often called *switched mode amplifiers*, not linear amplifiers, as in Class A, B or C.

The transfer curves of a Class C vs. Class D/E/F PA with a square wave drive is shown in **Fig. 4**. The gate is biased at 3v in both cases, and Vgs(th) is 4v. The amount of wasted input power is greatly reduced with the square wave drive. The output will have a slope on the rising and falling edges, due to the short time drain current must travel through the linear region. Still, the ON–OFF switching action of these modes is evident.

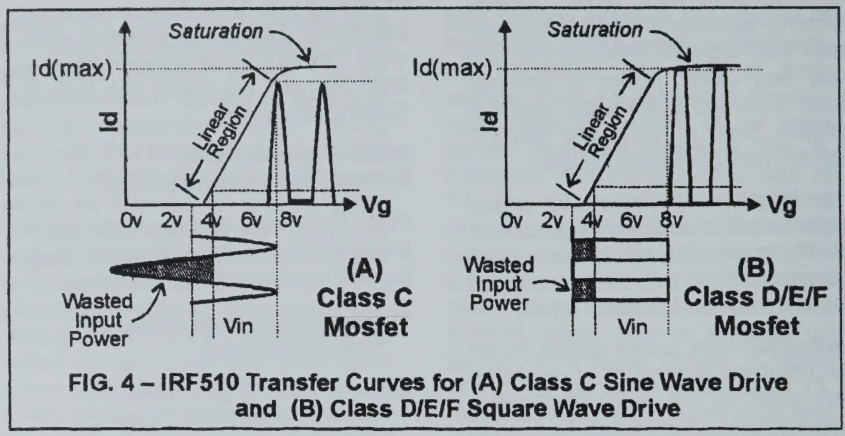


FIG. 4 – IRF510 Transfer Curves for (A) Class C Sine Wave Drive and (B) Class D/E/F Square Wave Drive

A square wave is an infinite combination of odd harmonics. The square wave output must be converted back into a sine wave by removing the harmonic energy before being sent to the antenna for FCC compliance. *The method by which the fundamental frequency is recovered from the square wave output determines whether it is Class D, E or F.* In all cases, it is based on driving the mosfet with a square wave input.

Legally, you can drive a mosfet into saturation with a huge sine wave as well, as many Class D/E circuits on the internet or ham radio publications are based. However, you are in the saturation region for a relatively short period of time (only during the positive input peaks), the rest of the time in the linear region. It is this authors opinion that the first step to increasing efficiency is avoiding the lossy linear region. This is defeated with a sine wave drive.

Therefore, the remaining discussion on Class D, E and F amplifiers are based strictly on a square wave drive.

It is worth mentioning an important distinction between the classes of amplifier operation. With *linear amplifiers*, the class of operation is based on the amount of time that collector or drain current flows: 100% for Class A, >50% for Class B, and <50% for Class C. However, the amount of time drain current flows in a *switched mode amplifier* has nothing to do with it's class of operation. It is based entirely on how the output power is transfered to the load and how harmonic power is removed.

CLASS D QRP PA

One implementation of a **Class D** QRP transmitter is shown in **Figure 5**. Note that there is little difference between the Class D PA, and the Class C mosfet PA shown in **Fig. 3**, other than being driven with a square wave and into saturation. One advantage of a square wave drive is it can be generated or buffered with TTL or CMOS logic components, making a 0v to 5v TTL signal, as shown. RV1 is again set for about 3v, which now corresponds to the 0v portion of the square wave, elevating the ON or HI portion of the square wave to +8v (+5V TTL + 3v bias), the minimum gate voltage to slam the mosfet into saturation. This is verified with an oscilloscope by monitoring the drain voltage, and noting that it falls nearly to 0v. A good IRF510 in saturation should drop to ≤0.4v.

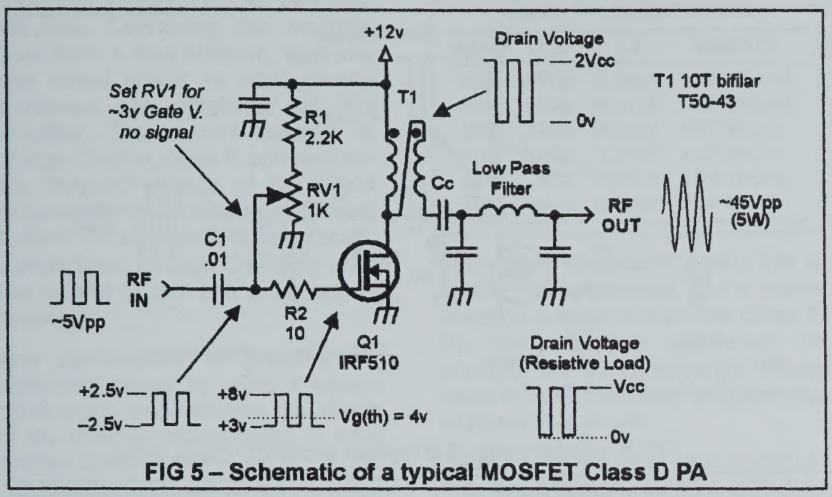


FIG 5 – Schematic of a typical MOSFET Class D PA

Speaking of oscilloscopes, having one is virtually required to properly build and tune Class D, E or F amplifiers. One must really be able to see what the waveforms look like, the voltages, and the timing (or phase) relationships to ensure the amplifier is operating properly.

The output circuitry is also identical to the linear Class C amplifier of **Fig. 3**, impedance converted through T1, followed by a traditional reciprocal (50Ω in – 50Ω out) low pass filter. Input resistor R2 is a low value resistor, 3.9Ω to 10Ω, to dampen the input Q a bit and prevent VHF oscillations. The value is not critical. A ferrite bead could be used as well (but a small value resistor more available).

Controlling the Output Power of the PA

Note that the input signal, as shown in **Fig. 4**, depicts a square wave with a 50% duty cycle. One of the beauties of switched mode amplifiers is the ability to change the output power by changing the duty cycle of the input square wave.

Remember that with an IRF510 in saturation, you are drawing about the maximum rated drain current, about 4A. This, of course, is way too much current to draw for any length of time. With the circuit shown, 5W is produced with about a 30% duty cycle, drawing about 800mA of total transmit current (including driver stages) for an overall efficiency of ~70%. You are "pulsing" the 4A ON and OFF to produce an *average* desired current, and hence output power. The shorter period of time the mosfet is ON, the lower the average power.

Final thoughts on Class D

Class D amplifiers were initially developed for hi-fideltity audio amplifiers, converting the audio into pulse width modulation (PWM). Class D really defines an amplifier that uses PWM for generating *varying* output power, such as audio.

The basic fundamentals have been applied to CW RF amplifiers, by simply driving the mosfet PA into saturation. Since these amplifiers do not use a PWM input (since a CW transmitter demands a constant

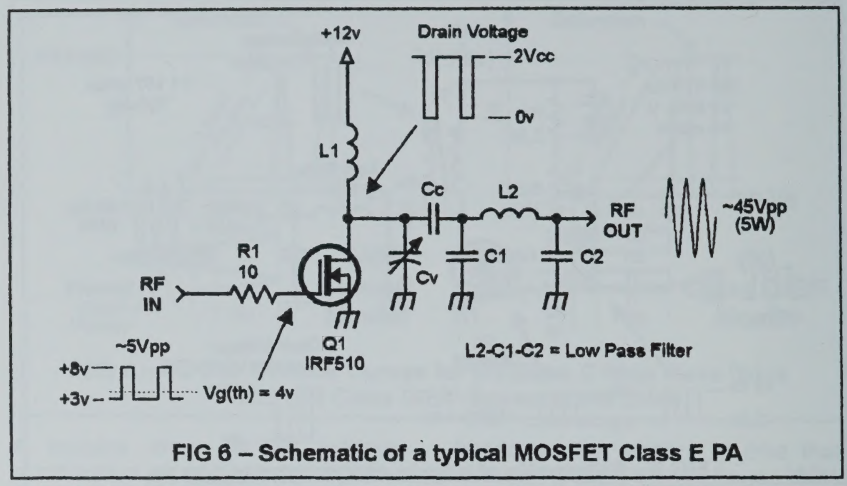
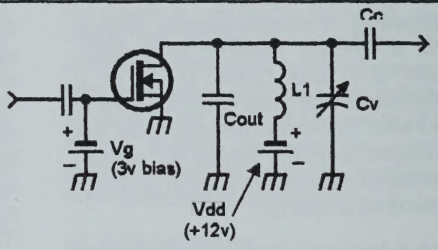


FIG 6 – Schematic of a typical MOSFET Class E PA

output power), they are not legally Class D. However, it has become accepted to refer to a mosfet PA, being driven into saturation *with standard low pass output filters*, as Class D.

For those wishing to experiment with these hi-efficiency switching amplifiers, start out with a simple Class D to see how they work and note the increase in efficiency. However, I would certainly recommend to any serious builder to graduate to a Class E PA.



Cout = Cds drain-source capacitance

FIG. 7 – Class E PA Parallel Equivalent Circuit

CLASS E QRP PA

The first **Class E** QRP transmitter to be considered is shown in **Figure 6**. The input is a 5Vpp square wave at the RF frequency, ranging between +3v and +8v due to the R1-RV1 bias network in **Fig. 5**, or as developed in the driver stage. The real difference, *which defines this circuit as Class E*, is the output side of the mosfet. A single inductor, L1, replaces the common bifilar transformer, and a variable capacitor, Cv, is placed from drain to ground. The output is capacitively coupled through Cc to the low pass filter.

To better understand this circuit, refer to the equivalent schematic in **Figure 7**. The IRF510 output capacitance, *Cout* or *Coss*, is 100-120pF, which would normally be an unwanted low impedance load to the drain circuit. However, in Class E, this output capacitance is used to our advantage by using it as part of a tuned circuit. Representing the +12v drain voltage as a battery, it can be redrawn to show how L1 is in parallel with *Cout*, forming a tuned circuit. Therefore, in Class E, the value of L1 is calculated to resonate with *Cout* at the desired output RF frequency. A fixed or variable capacitor, Cv, is usually added to the L-C circuit to reach resonance at the transmit frequency.

A parallel tuned circuit has very little net loss. Converting the mosfet's *Cout* from a loss element, to a low loss tuned circuit, is what *greatly increases the efficiency of this amplifier*. The current needed to charge Cout in Class E comes from the "flyback" energy of the tuned circuit, *not from the mosfet drain current*. In a properly tuned circuit, current flows through *Cout* only when the mosfet is OFF (no drain current flowing).

The combination of reducing the switching losses by using a square wave input, and reducing the effects of the internal capacitances, is what defines Class E.

Table 1 shows some initial starting values for the HF ham bands. *Cs* is the *total shunt capacitance* to add between the drain and ground – a fixed capacitor in parallel with the variable capacitor, Cv. On 40M, for example, this is a *total* drain-source capacitance of 240pF, including the internal *Cout* of the IRF510. The inductance, and the toroidal inductor to wind, is also shown to form the equivalent tuned circuit. I have built Class E PA's with these approximate values for all bands shown, except 80M, and all yielded an overall efficiency (total keydown current, including receiver and transmit driver currents) of at least 80%. However, these values need to be used with caution, primarily because the IRF510 *Cout* of 120pF, as listed on the data sheet, is for a Vd of +12v, that is, when the IRF510 is OFF. It rises to about 200pF as you approach saturation. The trick is to guestimate what the average IRF510 capacitance will be, depending on the duty cycle of the input square wave. To be truthful, it takes a little piddling around to get it right, but getting another percent or two of efficiency out of the PA is fun. In fact, it can become an obsession! Again, this is where an oscilloscope, and a power meter, is a must to tune the Class E PA for maximum efficiency. In practice, the *Cs* capacitance values listed in Table 1 will likely end up being a bit less than shown.

Table 1 – Initial Values

BAND	Cs	L1	WIND L1
80M	270p	5.0uH	10T T50-43
40M	120p	2.1uH	6T T50-43
40M	120p	2.1uH	20T T50-2
30M	120p	1.0uH	14T T50-6
20M	47p	0.8uH	13T T50-6
15M	—	0.5uH	10T T50-6

Note the square wave input shown in **Fig. 6** is depicted having a 30% duty cycle, not 50% in the Class D circuit. Output power is determined by varying the duty cycle of the input drive. With Class E, it is my experience that maximum efficiency occurs around 45% duty cycle of the input gate drive (45% ON, 55% OFF).

CLASS E QRP PA with Series Tuned output

Figure 8 shows another implementation of a Class E amplifier. Instead of using an LPF output filter, a combination of parallel and series tuned resonant circuits are used. As in the first example of the Class E amplifier, L1 forms a parallel tuned circuit with the total shunt capacitance of Cv and the internal drain-source capacitance of *Cout*. Instead of following this with a low pass filter, it is followed by a series tuned resonant circuit, consisting of L2 and C2. The combination of the two tuned circuits is sufficient to ensure FCC compliance for harmonic attenuation.

From my experience, the difficulty with this approach is selecting the component values to effect a proper impedance match to the 50Ω load. It

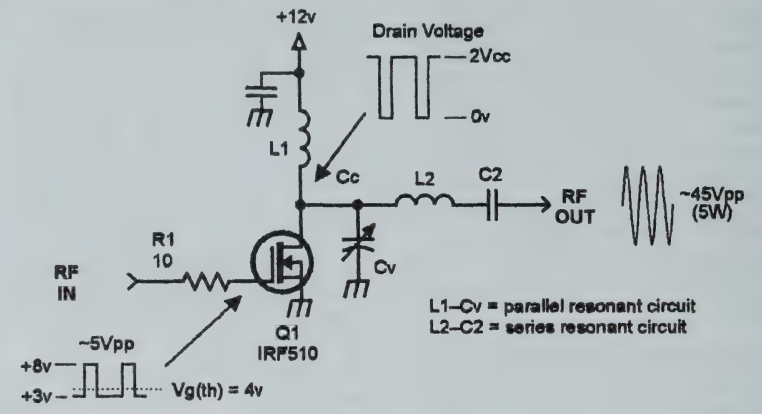


FIG. 8 – Class E Transmitter with Series Tuned Output

can be done with a little math, computer modeling, or experimentation, but again, due to the uncertainty of the actual IRF510 *Cout* value and resulting average output impedance, a fair amount of tweaking is required. Once the output impedance is properly transformed into 50Ω at the antenna, and L2–C2 tuned for resonance, the efficiency will be about 85%. However, with the L2–C2 series tuned element, it becomes rather narrow banded and efficiency drops when the frequency is moved about 10KHz. A variable capacitor across C2 will allow retuning upon frequency changes, although in practice, this is cumbersome for the way most of us prefer a no-tune QRP transmitter.

There are still other ways to implement the Class E amplifier, such as additional parallel or series tuned circuits on the output, or using impedance transformation schemes. It is an area worthy of further development by hams and QRPers. The main goal is to use the internal drain-source capacitance as part of the parallel tuned output circuit with the drain inductance. This will generally require some additional capacitance between drain and ground, and some means to tune it to resonance. By doing so, the output capacitances are charged from the "flywheel effect" of the tuned circuit, that is, current from the drain inductor, not from the drain current. The later is wasted energy, which lowers the efficiency.

CLASS F QRP PA

The square wave *drain voltage* is rich in odd harmonics, predominantly the 3rd and 5th harmonics (3fo and 5fo). A sinewave with odd harmonics will be flattened at the peaks (at 90° and 270°), lowering the efficiency of the PA. Upon removing the odd harmonics, it will be a proper sinewave. In a typical QRP transmitter, the harmonic power is thrown away by the low pass filter. However, if one were to use this odd harmonic power in proper phase, the power could be added to the fundamental frequency to boost the output power. This would increase the efficiency of the amplifier.

This is the essence of Class F. The output network consists of odd harmonic peaking circuits in addition

to resonant circuits at the desired fundamental frequency. This forms the clean output sine wave, and the odd harmonic peaking adds a bit of power to the fundamental to increase PA efficiency.

Figure 9 shows one approach to accomplishing this. Component values are chosen such that L2–C2 is resonant at the 3rd harmonic, and L1–C1 and L3–C3 resonant at the fundamental frequency.

To analyze the circuit, consider the functions of these networks at different frequencies.

At the 3rd harmonic (3fo), L2–C2 is resonant, their reactances cancel out, offering little resistance to the 3fo voltage, passing the 3fo power to the L3–C3 network. L3–C3 will appear capacitive at 3fo, and will be charged with the 3fo power.

At the fundamental frequency (fo) L3–C3 is resonant, with a slight boost in power due to the voltage added to the network by the 3fo peaking circuit described above. At fo, L2–C2 (fr=3fo) will appear inductive, and the value of C1 is selected to form a series resonate circuit at the transmit frequency with this inductance. Normally, C1 is a dc blocking capacitor, usually 0.1μF. In Class F, C1 will be a few hundred pF, depending upon the fo.

Obviously, it takes some math to figure out these values for the respective resonances, and to achieve the proper impedance transformation to a 50Ω load.

I have built several Class F amplifiers, using an impedance network analyzer to verify the impedances, capacitance and inductance of all elements at fo, 2fo and 3fo. Inspite of being properly tuned, I have never been able to reach an efficiency higher than what I've obtained with Class E. It is my opinion that the extreme complexity of Class F is not worth the effort over Class E *at QRP levels*. Class F is used in commercial 50kW AM transmitters, and at even higher powers for shortwave transmitters. Perhaps the extra 1–2% of efficiency is worth it for saving a kilowatt at these power levels, but is

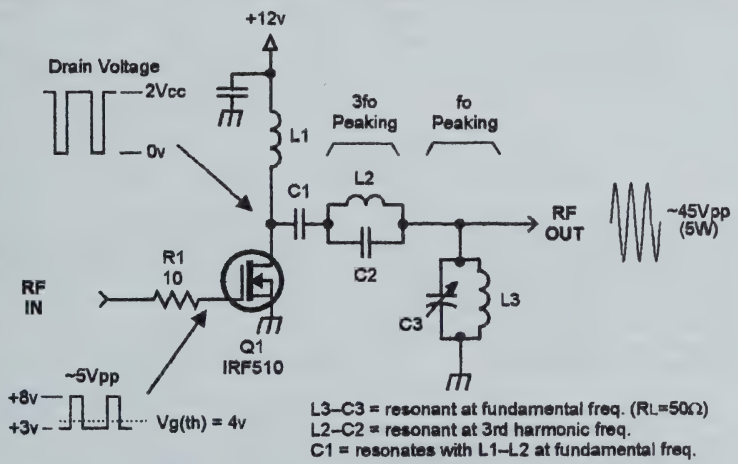


FIG. 9 – Class F Transmitter with Harmonic Peaking

scarcely measurable at QRP powers.

None-the-less, Class F is a clever approach to increasing efficiency, and presented here for sake of completeness of the high efficiency modes.

Conclusion.

These switched mode PAs are ideal for QRP, in that the higher efficiency directly relates to lower battery drain. It is worthy of further development by QRPers, and the reason the theory has been presented in the first part of this article.

In **Part 2** – a more technical approach to Class D/E/F will be presented, along with details of the gate input drive requirements and suitable driver stages, with actual oscilloscope waveforms. The IRF510 Data Sheet is also included in Part 2.

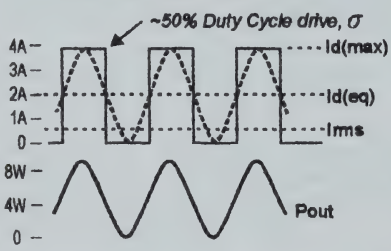
In **Part 3** – two complete construction projects: the NA5N Class D and Class E transmitters. Both include a high speed comparator, which converts the 50–500mVpp RF signal from a TX mixer into a square wave. It also includes the PWM circuitry for varying the pulse width for variable output power. Both are based on the IRF510, and yes, illustrations are based on *Manhattan Style construction*®! These can be built and added to about any QRPp transmitter for 5W output (and sometimes more!)

For those interested in Class D/E/F, I hope you have found the information in Part 1 informative. For those of you building such circuits, I would be interested in hearing of your success and approach.

72, Paul Harden, NA5N
na5n@zianet.com
pharden@nrao.edu

Appendix A – Pulse Width Modulation (PWM) or varying the duty cycle to control output power

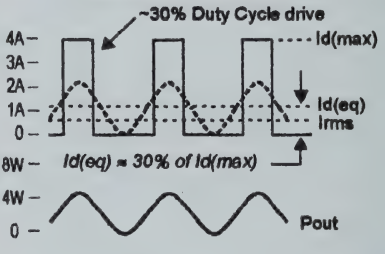
50% Duty Cycle Drive



Consider the drain output current above with a 50% duty cycle and the IRF510 Id(max) of 4A. The sinewave equivalent is shown as the dotted wave-form. Id(eq) is effectively converting the peak-to-peak current to peak current (at 50% duty cycle), then converting to Irms to determine output power, as calculated below.
σ = duty cycle, η = PA efficiency

Id(eq) = σ Id(max) = 50% x 4A = 2A
Id(avg) = .637Id(eq) = .637 x 2A = 1.3A
Irms = .707Id(avg) = .707 x 1.3A = 0.9A
Po = IrmsVddη = 0.9A x 12v x 80% = 8.8W

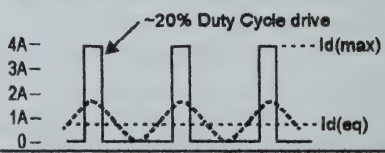
30% Duty Cycle Drive



Id(eq) = σId(max) = 30% x 4A = 1.2A
Id(avg) = .637Id(eq) = .637 x 1.2A = 0.76A
Irms = .707Id(avg) = .707 x 0.76A = 0.54A
Po = IrmsVddη = 0.54A x 12v x 80% = 5.2W

20% Duty Cycle Drive

What is the Output Power at σ= 20%?



HF Vertical Travel Antenna - Updated:

Phil Salas - AD5X

Introduction

I've had a tremendous response to the portable antenna project published in the July 2002 QST. Since this antenna has been so popular, I've continued to improve and simplify it. In the last several months I've evolved the antenna from the original riser design, to a fiberglass design, and now to an aluminum tube design. This new design is lighter and more compact than the original antenna. It is also easier to build, and easier to find parts for.

As before, this new version of the Travel Antenna is designed for easy transport. It breaks down into multiple mast and whip sections, an air-wound center loading coil section, and a small base support with no piece longer than 2-feet so it will easily fit into most suitcases. Yet the fully assembled antenna has a length in excess of 12-feet.

Gathering the parts:

The loading coil, half of a B&W 3027, is available from Surplus Sales of Nebraska. (www.surplussales.com)

The 3/8" aluminum tubing is found in many hardware stores - or it can be ordered from Texas Towers $25 min order at: www.texastowers.com

The parts list is as follows:

Three 24" pieces of 3/8" diameter aluminum tubing ($4.20/6' tube from Texas Towers)*

One 3/8" diameter wood dowel ($1.28/36" @ Home Depot - only 5-1/2" needed)

One-half of a B&W 3027 coil ($20 shipped from Surplus Sales of Nebraska)

One 72" telescoping antenna ($4.99 @ Radio Shack 270-1408B/270-1408/27-1408)**

One 3/4 x 3/4 x 1/2" PVC-T ($0.20 @ Home Depot)

One 3/4"-to-1/2" pvc adapter ($0.50 ea @ Home Depot)

One 3/4" PVC Plug ($0.89 ea @ True Value)

One 1/2x1/8-NPT brass adapter ($1.20 @ True Value)

Eight 1/8-NPT brass couplings ($0.95 ea @ Home Depot)

Four 1/8-NPT 0.7" all-thread nipples ($0.75 ea @ Home Depot)

One 1/8-NPT 1" nipple ($1 @ True Value)

One #8 wing-nut ($0.34 @ True Value)

Three #8 x 1" brass screws ($0.08 ea @ True Value)

Three #8 brass nuts ($0.83/6 @ Home Depot)

Three #8 copper-plated steel split lock washers ($0.05 ea @ True Value)

One 3/8x16 x 12" hex head carriage bolt, zinc plated ($1.18 @ Home

Depot)
Two 3/8x16 nuts, zinc plated ($0.83/6 @ Home Depot)
One 3/8 lockwasher, zinc plated ($0.83/10 @ Home Depot)
Ten #6 stainless steel 3/8" sheet metal screws ($0.07 ea @ True Value)
Six #6 stainless steel lock-washers ($0.05 ea @ True Value)
One chassis-mount SO-239 coax connector ($1.99 @ Radio Shack - RS278-201)
One #8 spade lug (Home Depot)
72 ft wire (Any gauge, insulated or not, for six 12-foot ground radials)
Six #8 x 1-1/2" brass wood screws ($0.83/6 @ Home Depot)
* True Value and ACE Hardware stores have tubing areas with shorter pieces of aluminum and brass tubing. I found 3/8"OD x 3' aluminum tubes for $2.50 each, and 3/8"OD x 3' brass tubes for $4.50 each. So you can either go with two 3' tubes, or four 1-1/2' tubes if desired. Also, with brass tubes you can solder the couplings directly to the tubes. Make sure you adjust the brass couplings/nipples quantities as needed.
** This Radio Shack part is very confusing. All three of these numbers refer to the proper 6-section 72" whip. It seems to depend on the phase of the moon as to what the Radio Shack catalog, web site, and actual store inventory part has on it.

Aluminum Rod Preparation and Assembly:

See Figure 1 for the assembly details. In order for the couplings to fit over the aluminum tubes, the ends of the couplings that fit over the tubes must be reamed out with a 3/8" drill bit. To do this, first screw a 1/8-NPT coupling on each end of a 0.7" 1/8-NPT nipple. Use pliers and/or wrenches to screw these on tight. Next, grasp one of the couplings with a pair of vice-grips and ream out the opposite coupling with the 3/8" drill bit. Reverse, and ream out the other coupling. Now unscrew the couplings. One end will brake loose, and the other will stay tight in the remaining coupling. You'll now have a female and male end that will fit over each end of the aluminum tubes. You will need four pairs of these male/female brass connectors: three pairs for the aluminum tubes and one pair for the loading coil assembly. If you'd like, you can solder the nipple/coupling assemblies together, however the nipple/coupling assembly tends to be very tightly secured. Finally, drill 9/64" clearance holes into the ends of the **three** coupling pairs that will slide over the aluminum tubes. These holes will pass the #6x3/8" stainless steel sheet metal screws that will hold the couplings to the aluminum tubes. Please note that the fourth coupling pair is used on the loading coil assembly and will be drilled and tapped for #8 brass machine screws.

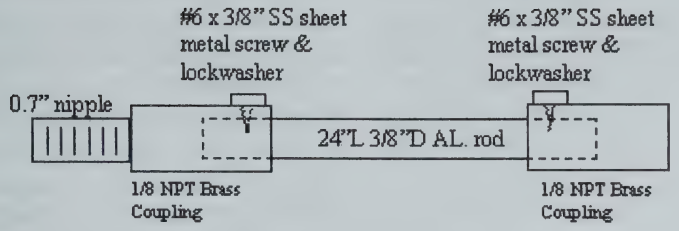

#6 x 3/8" SS sheet metal screw & lockwasher
#6 x 3/8" SS sheet metal screw & lockwasher
0.7" nipple
24"L 3/8"D AL. rod
1/8 NPT Brass Coupling
1/8 NPT Brass Coupling

Figure 1 - Middle Sections, no coil (3 ea)

Next cut three two-foot sections of the 3/8" aluminum tubes with a hacksaw or tubing cutter. De-burr the tubing, and also slightly file the edges of the tubing to make it easier to push into the brass couplings. As shown in Figure 1, insert the male/female brass pairs just constructed over all three of the aluminum 24" tubes. This could be a tight fit, so you may need to tap the couplings in place with a hammer. Since brass and aluminum are significantly dissimilar metals, you may want to coat the aluminum tube ends with DeoxIt, Noalox or Penetrox to prevent possible corrosion, especially if the antenna will be outside for extended periods of time. To tap the couplings in place, insert the male/female coupling pairs over the 3/8" aluminum tubes as best you can. Then place the nipple-end (male) on a piece of wood, and gently tap the opposite side of the rod (female coupling) with a hammer until the couplings are fully seated. Now, using the 9/64" clearance holes in the couplings as guide holes, drill 7/64" diameter holes through the aluminum tubes, and attach the risers to the aluminum tubes with the #6x3/8" sheet metal screws and lock-washers as shown in Figure 1.

Loading Coil Assembly:

Refer to Figure 2 for the loading coil section. Here, 1/8-NPT male/female coupling pairs are slid over a 3/8" diameter 5-1/2" long wood dowel. You will need to drill and tap a #8 threaded hole through one side of each of the 1/8-NPT brass couplings and into the wooden dowel as shown in Figure 2. Note that the screws are on opposite sides of the rod. Insert the

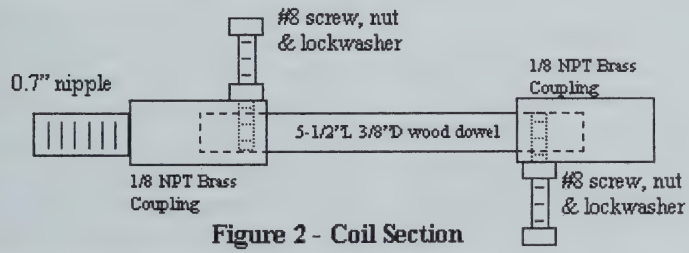


Figure 2 - Coil Section

two #8 x 1" brass screws through #8 nuts and lock washers as shown. Tighten the nuts to secure the screws in place. These screws will be used for the coil support.

Now cut off a 5" length (half) of the B&W 3027 coil. Using a screwdriver, indent every other turn of the coil. Position the coil over the screws such that the 1" long brass screw heads extend just above two adjacent turns on each end of the coil. Solder these two turns at each end to the screw heads. On the end of the wood dowel coil form with the brass nipple (male end), solder a 6" piece of insulated wire terminated with an alligator clip.

For extended outdoor use, you may wish to treat the wood dowel with varnish, replace it with a piece of 3/8"D x 5-1/2"L fiberglass rod, or use the riser assembly as shown in the original QST article (July 2002).

Top Whip Preparation:

File the plating off the small mounting stub at the base of the Radio Shack 72" collapsible whip antenna. Once the bare brass is exposed, tin this with solder. Now insert the whip antenna base into the 1/8-NPT x 1" brass nipple such that the antenna base is just below the lip of the nibble. Temporarily hold these pieces together with some masking tape. Now heat the nipple with a soldering iron and solder the brass antenna base to the inside of the nipple. Incidentally, I found that some brass nipples were a little small on the inside to pass the collapsible whip. Nipples I purchased at True Value hardware cleared the whip, and nipples purchased at Home Depot didn't. If you can't find a nipple with a 0.275" ID, you can drill the nipple out with a 9/32" drill bit. Hold the nipple with a hefty pair of vice-grips when you do this and you won't have a problem!

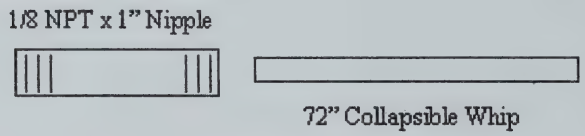


Figure 3 – Collapsible whip assembly

Base Assembly:

In this design, I've used a 3/8x16 x 12" zinc plated hex head carriage bolt instead of the original brass threaded rod. Only about the last 1-1/2" of the carriage bolt is threaded, so it is much easier to clean off the bolt after use. The threaded rod was always a pain to clean. With the carriage bolt, a damp cloth easily cleans it. To prepare the carriage bolt, cut off the hex head and round this end with

a file. Referring to Figure 4, drill a 3/8" diameter hole into the 3/4" PVC plug used for the ground support carriage bolt. Cut off about half of the length of the 3/4" PVC plug to leave plenty of room inside the "T" for wiring, insert the carriage bolt threaded end into the plug, and secure with two 3/8x16 nuts and a lock washer as shown. I prefer soldering ground wire to the internal 3/8x16 nut as show. However, this is really not necessary, as the radials will provide the antenna ground - both RF and DC. If you wish, you can PVC-glue the plug in place instead of using the #6 stainless steel sheet metal screws shown. However, the screws make changing the support assemble easy in case you want to have a second support assembly made from threaded rod for mounting onto a trailer mount, metal plate, etc.

Next, place the SO-239 temporarily over the 1/2" hole in the "T" and mark the location for the two #6 x 3/8" long stainless steel machine screws that will hold it in place. You'll see that these holes will be right in the center of the PVC lip. Carefully drill two 1/16" holes at these points. Place the 3/4" PVC plug/spike assembly in the "T" and

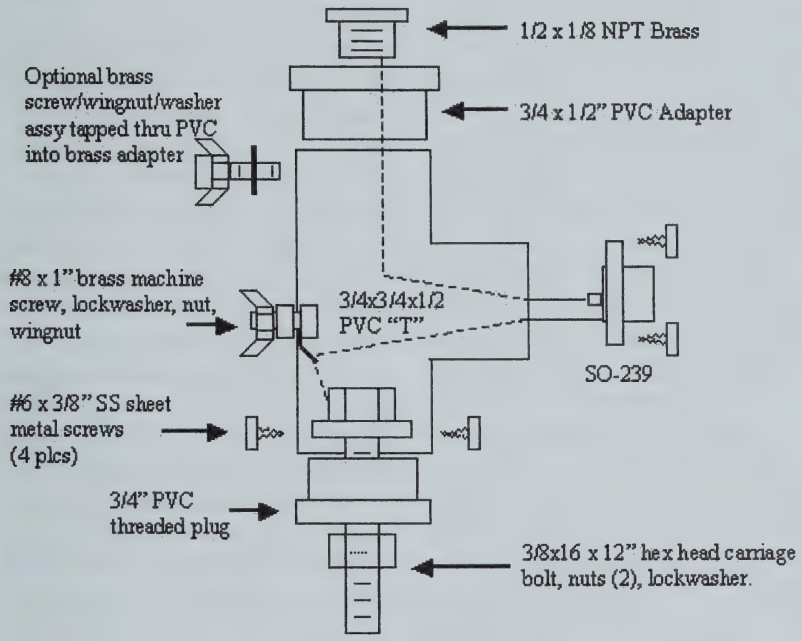

1/2 x 1/8 NPT Brass
Optional brass screw/wingnut/washer assy tapped thru PVC into brass adapter
3/4 x 1/2" PVC Adapter
#8 x 1" brass machine screw, lockwasher, nut, wingnut
3/4x3/4x1/2 PVC "T"
SO-239
#6 x 3/8" SS sheet metal screws (4 plcs)
3/4" PVC threaded plug
3/8x16 x 12" hex head carriage bolt, nuts (2), lockwasher.

Figure 4 – Base Assembly

drill two 1/16" diameter holes through the "T" and plug. Remove this assembly from the "T" and drill out these 1/16" holes in the "T" to 1/8". Also drill out two holes in the SO-239 connector to 1/8" since the holes are not large enough to pass the #6 x 3/8" sheet metal screws.

Next we'll prepare the antenna interface at the top of the base. First, cut off part of the 3/4 x 1/2" PVC adapter so as to leave additional room in the "T" for wiring. Solder a piece of #14 copper house wire directly to the inside lip of the 1/2 x 1/8NPT brass adapter. You'll need a large soldering iron or a torch since the brass adapter mass is pretty large. Screw this adapter tightly into the 3/4 x 1/2" PVC adapter.

Finally, solder wires to the center conductor and to the ground of the SO-239 connector as shown. The wire from the center conductor should be soldered to the wire stub on the 1/2 x 1/8NPT brass adapter at the antenna interface, and then the 3/4 x 1/2" PVC adapter can be PVC-glued into place. I used a short piece of copper braid from a piece of RG-58 cable from the SO-239 ground (soldered directly to the SO-239 body) to the brass ground screw. You can solder the braid directly to the head of the brass ground screw. You can now complete the assembly of the base by inserting the PVC plug/12" carriage bolt assembly into the "T" and installing the #6 stainless steel sheet metal screws as shown in Figure 4. As you can see in Figure 4, I also made provisions for an optional wing-nut assembly in case you need to add capacitive or inductive base matching should you significantly shorten the antenna, or if you have a very good groundplane and want to improve your VSWR. To make this wing-nut assembly, screw a brass wing-nut tightly against the head of the brass screw and solder these together.

Ground Radial Network:

The radial network is made up six 12-foot radials using #22 insulated wire though any gauge wire, insulated or not, can be used. Attach all the wires together and to a #8 spade lug on one end. This lug will attach to the groundThe radial network is made up six 12-foot ra-

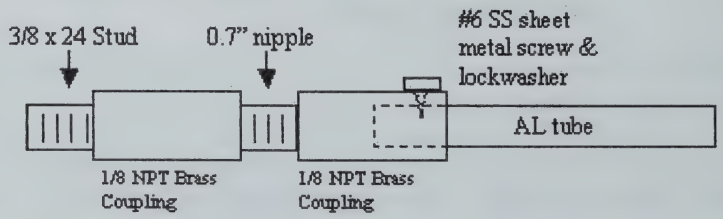


Figure 5 – Adapt to Standard 3/8x24 base

dials using #22 insulated wire though any gauge wire, insulated or not, can be used. Attach all the wires together and to a #8 spade lug on one end. This lug will attach to the ground screw on the base assembly. Roll up the six wires individually and hold them together with tie-wraps to minimize the time spent in unraveling the wires. On the outer end of each radial, solder on a 1-1/2" brass wood screw. These screws are pushed into the ground to help hold the radials in place. I put a blob of hot glue on the wire/screw interface to give it a little strain relief.

Antenna Assembly

To assemble the antenna, first screw two 24" aluminum rods together, and then screw these into the top of the base assembly. Push this base/rod assembly firmly into the ground, keeping it as vertical as possible. Next screw the remaining 24" aluminum rod, the loading coil, and telescoping whip assemblies together. Extend the telescoping whip. Screw this entire top assembly into the female end of the 24" aluminum tube that is available on the assembly currently pushed into the ground. Finger tight is all that is necessary for all brass fitting interconnections. Finally, extend the six radials, and attach the common end to the ground screw on the base assembly.

Antenna Set-up

To find a permanent coil tap for each band, start with 40 meters and use an antenna analyzer to find the coil tap that gives the best VSWR. Mark this tap point. You may want multiple taps on 40 meters so as to cover both the CW and SSB portions of the band. Move to 30 meters and repeat. Repeat again for 20 and 17 meters.

For 15, 12 and 10 meters, the entire coil is shorted. The telescoping whip is adjusted for resonance. Use a permanent black marker pen to indicate the high band positions on the telescoping whip.

Now solder short pieces of wire to the tap points determined for all bands where the coil is used. From this point forward, you can just go back to these tap points, or re-adjust the top whip as necessary, and not have to worry about making VSWR measurements. You'll find that in all cases the VSWR should be under 1.5:1.

Guying and Mounting Options

This antenna is self-supporting in a no- to low-breeze environment. In many cases it may be necessary to guy the antenna. For effective guying, attach packing twine (3 pieces) around the bottom coil support brass coupler. Extend the twine and attach to tent stakes, nearby shrubs, etc. If you wish to bolt the antenna base directly to a trailer mount or plate, use a 3/8" threaded rod (brass or zinc-plated steel) as discussed earlier instead of the 12" carriage bolt "spike". In this case you should solder the

ground wire inside the "T" to the 3/8 x 16 nut as shown to ensure a good ground to whatever the base is mounted to.

Finally, you can easily make a 3/8x24 standard interface so that the antenna can be mounted on a standard 3/8 x 24 ham mount (most antenna mounts require a 3/8x24 stud on the antenna). It turns out that the 1/8-NPT thread is just a slightly tapered 3/8x24 thread. So, purchase a 3/8x24 bolt (your local hardware store again) and screw it tightly into a 1/8-NPT coupling. Cut off the head of the 3/8x24 bolt with a hack saw and file carefully so that the threads are OK for screwing into a 3/8x24 socket. You can now either screw this assembly onto the 1/8-NPT nipple on the bottom fiberglass rod section (See Figure 5), or screw the 3/8x24 bolt directly into the bottom 1/8-NPT coupling as shown in Figure 6 (if you'll never need the 1/8-NPT interface on the bottom antenna section). Now you can mount this antenna on any standard 3/8x24 antenna mount.

Conclusion

Due to the heavy interest in my portable antenna, I've made some changes which makes the antenna lighter, more compact, easier to fabricate, and also gives you more mounting options. You can also experiment with the antenna length – i.e. remove a section or two, use more or fewer sections, decrease or increase sections lengths, or place the loading coil in different positions. And how about 75-80 meters? You bought twice as much coil as you need, so build up a second coil assembly and put both coil assemblies at the base of the antenna. No need to indent or add an alligator clip to this coil. However, there is an efficiency penalty for base-loaded versus center-loaded antennas (but you must use base loading to reach 75-80 meters with this antenna). Also, you will need base capacitive loading to get the VSWR down on 75-80 meters. And finally, don't hesitate to make changes based on hardware availability. Try brass or copper tubing, or even wire

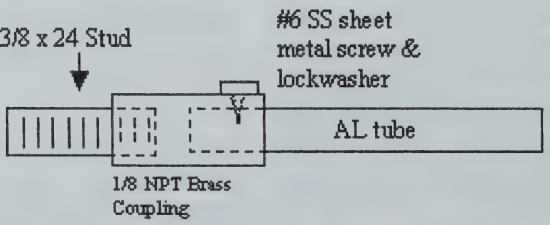


Figure 6 – Alternate Adapt to Standard 3/8x24 base

wrapped 3/8" fiberglass or wood dowel. Its fun to design antennas "on the fly" while standing in the plumbing section of your hardware store. This makes for interesting discussions with the clerks, however!

Phil Salas – AD5X – can be reached at ad5x@arrl.net if you have any questions or comments. This is an easy and fun antenna to build, and the total cost should be under $60.

A Review of Short Antenna Design

Jim Pepper W6QIF

My experience with short vertical antennas started when ham radio was first allowed mobile operation on the HF bands in the early fifties. Up to that time, mobile operation was allowed only on the VHF and UHF bands. The very first day after the restriction was lifted I was on the air with a crude antenna on my car and contacted W6RJY (Floyd Becker) located about 2 miles from me. As time went on, many improvements in mobile antennas were made. A group of us would go to an open field near the Oakland airport to compare various antenna designs. We would move up to a given marker and each would transmit for a short period so home base stations could take a reading on their S meters. There were generally several stations giving reports. The antennas ranged from base loaded to top loaded to center loaded or combinations of these. There were some that had a loop going from the rear bumper to the front bumper. On the average, the center loaded antennas gave the best efficiency and those with top capacitance loading with a center coil were the best. Corrections were made for power variations.

There were various types of top capacitance loading. Some were really bizarre. However, they couldn't be truly mobile because of their size.

SHORT VERTICAL ANTENNA DESIGN

For many hams it is sometimes difficult to string up a dipole for various reasons. If an efficient short antenna were available, this could satisfy many in this unhappy position. There are also occasions when one would like to operate in a field situation or on vacations, and finding a suitable set of trees for attaching a dipole is not easy, especially on a beach front area. So what is a good design for a short vertical antenna for other than mobile use? The principles are also applicable to mobile types of antennas with some restrictions.

To put up a quarter wave vertical for field operation on 40 meters is next to impossible unless you have a tree that is 33 ft high. And it still requires a good ground or counterpoise. A shortened version requires some sort of inductance to bring the system back to resonance because it is primarily a capacitive reactance. Where this inductance is placed can determine the efficiency of the system. The efficiency is defined as the radiation resistance (Rr) divided by the summation of Rr+Rg+Rc where Rc is the rf coil resistance and Rg the ground resistance. Rr depends on the length of the antenna as well as the frequency of operation, Rc depends on the coil "Q" and Rg, the ground system, which depends on the ground conductivity and/or by an artificial surface equivalent to the ground in the form of multiple radials.

The radiation resistance of a short antenna (8 foot) at 7 mHz is quite low, in the order of 1 to 6 ohms depending on the type, therefore to keep the efficiency up, the losses from Rc and Rg must be minimized.

SWR MEASUREMENT (1)

A low SWR measurement at the base of the antenna is usually considered an indication of the fact that the antenna is doing a good job of being efficient. This is not necessarily true. For example, if the reading is a SWR of 1:1 is obtained with no line matching transformer and the SWR =Zo/Rt where Zo is the transmission line impedance, then Rt would then equal 50 ohms. Rt=Zo/SWR Thus, with an SWR of 1:1 with no matching transformer and the Rr for an 8 ft base loaded antenna being about 2 ohms at 7MHz, the efficiency would be 2/50 or 4%. Not very efficient But a more efficient antenna would record a higher SWR reading when connected to a 50 ohm line with no matching. For example, a vertical with a radiation resistance (Rr) of 4 ohms and no other losses would have an SWR of 12.5:1. SWR=50/4=12.5 Rr/Rt=4/4=1x100 or 100% It would be 100% efficient but would require a matching network at the base to reduce the SWR to 1:1.(4 ohms to 50 ohms).

In any case, it is most likely that a matching network will be required at the base on all short antennas to improve the efficiency. So one can see that having a low SWR doesn't mean you have an efficient radiator although it may allow the transmitter to apply power to the antenna. It probably means that your losses from the coil and ground system have added up to give you a good match.

A high SWR can be ignored if the transmission line is very short as in the case of a mobile system. The mismatch can be corrected at the transmitter. However, with a field operation, it not wise to sit close to the radiation system therefore matching would be required. But even with matching you are still lim-

ited by the radiation resistance for the performance of the antenna.

SHORT VERTICAL ANTENNA DESIGN

Good HF radiating antennas come in various forms and I am sure you are well aware of the different types. I want to discuss one special type of radiator, that of a short vertical antenna, short meaning less than 1/6 wave in length. The vertical antenna in this discussion is for the 40 meter band but could be scaled to other bands. As a matter of fact the design I will describe will cover both the 40 and 30 meter bands with a small modification. The overall height is approximately 8 feet.

There are a number of antennas that fit this category of short antennas, both commercially built as well home brew. So what are the considerations on designing such an antenna if you want to try building one of your own to obtain maximum efficiency?

One way to look at any antenna is that it must be a resonant circuit to give maximum efficiency. Note, I said maximum efficiency. It is possible to get any length of wire to radiate if proper matching is provided to the power source but may have very low efficiency depending on the length of the wire and frequency of operation.

A BASIC ANTENNA FIG 1

Let us consider an LC tuned circuit and open up the capacitor plates so they are far apart. If the capacitance plates are increased by making them larger in physical size the system can still be resonated to the desired frequency. Thus we have the basis of a radiating antenna system. There is an exchange of RF voltage and currents between the two plates setting up a dielectric field that will produce radiation. With the vertical antenna, the field is set up between the capacitance of the antenna rod and the conductivity of the ground system that returns the current back to the source. This is called the induction field and varies as the inverse square of the distance from the source. How much is returned depends on the losses in the ground system. On a vertical antenna, the ground system can consist of a single wire some times called a counterpoise, a large number of wires called radials, or even a wire screen. It is vital that this return path be provided to produce a resonant system. It is also aided by the conductivity of the earth itself.

Now, in the case of a short antenna, how long and how many of these wires are needed? Let us go back to the concept of the LC circuit. If we had a capacitor that had a large plate on one side and a small plate on the other, the actual capacitance would be predominately determined by the smaller plate. This turns out to be the case with a short vertical antenna.(2) It does not help much to have a large

ground plane when the source is a small capacitance. In fact I found a ground plane longer than the height of the antenna did not improve the efficiency to any meaningful extent. In addition, because the primary induction field decreases as the inverse square of the distance, the effect on the return is greatly diminished the further out it goes. This is not the case of the radiated field which is lost in space and never returns to the source. This field is influenced by the earth ground system and thus determines what the effectiveness of the radiated signal has after it leaves the antenna.

As previously stated, the short vertical is seen as a capacitive reactance and therefore, to bring it to resonance, an inductance must be added. To do this, a coil must be placed in series with the antenna rod or wire. Such a coil, however, produces a loss in the system due to the coil resistance at rf frequencies. An alternative is to increase the capacitance and to reduce the capacitive reactance, thus requiring less inductance to bring the system into resonance. To add capacitance, the size of the vertical rod's diameter provides some influence, but going from a wire to 1/8 inch diameter doesn't have much effect. However, going from 1/8 to 1/2 inch gives about 20 percent increase in capacitance. The capacitive losses can be kept much smaller than inductive losses. I am not referring to the ground losses which must be dealt with separately. So where are the losses in a short vertical radiator? We have the radiation resistance (Rr) loss but we want to maximize this because this is the power lost to radiation, our primary goal. Rr is dependent on the physical length of the vertical as well as the frequency of operation. Other losses we want to keep to a minimum because these losses reduce the efficiency of the antenna.

As previously stated, the two major sources of loss are the coil loss and the ground loss and the system is basically an LC system thus we want to keep the inductance small and the capacitance large. There are two ways to increase the capacitance. Increase the diameter of the radiating rod and/or use top loading capacitance which also effectively increases the length of the antenna and at the same time increases the Rr of the antenna. Or do both. The coil loss can be identified by a factor called the "Q" of the coil. The Q is defined by the ratio of the coil impedance divided by the RF resistance of the wire of the coil at the frequency of operation. Typically we want to achieve a Q as high as possible to keep this loss to a minimum. What are the factors that effect the Q of a coil? There are a number of them. First is the diameter of the wire and the material of the wire. The larger the better but obviously there are limitations to this.

The material should be one of good electrical conductivity. (Note: The RF currents only travel on the outer surface of the wire, thus the core can be open as in the case of tubing.) Another factor is the shape of the coil. The larger the diameter of coil, the higher the Q. Again there are limitations on this. The ratio of the length to diameter has an effect on the Q. The diameter should be greater than twice the length of the coil although this is not a strict rule, but it should not go to far from this value to achieve a high Q (3).

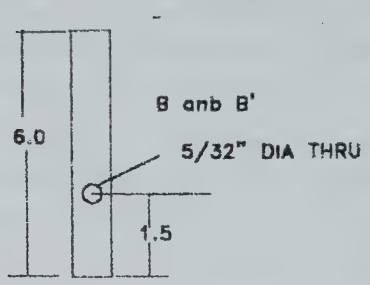
Other factors that effect the Q are: 1. the proximity of a metal object close to the coil. They should be kept at least a coil radius away from the coil. 2. The material of the coil form should be low loss such as plexiglass, or better, air. And finally the distance between adjacent wires on the coil. The capacitance effect between turns will lower the Q. As a rule of thumb, the spacing between turns should be about the diameter of the wire.

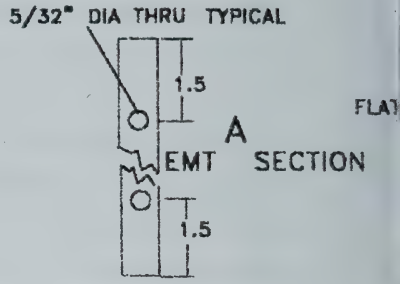
Since the inductance is inversely proportional to the square of the diameter of the coil, if you increase the diameter by 2, the number of turns is reduced by 4. The reduction in the number of turns reduces the resistance loss of the coil for a given size of wire thus aids in increasing the Q of the coil. It has been shown that, if the inductance is placed in about the middle of the vertical, it results in a higher radiation resistance than using base loading.(4) Most of the current that produces radiation mainly lies below the coil and thus it is best to keep this as long as possible. There is radiating current above the coil as well, but it drops off radically as it approaches the end of the antenna. The problem with putting the coil in the middle is that it requires more inductance than with base loading since the capacitance above the coil, to the ground plane, is now reduced. The capacitance above the coil is the source for primarily producing a resonant system. This means greater care must be employed to keep the Q of the coil high to overcome this loss due to the increase in inductance.

Of course the best place for the coil would be at the top of the antenna giving the maximum region for the radiation current. This requires an even larger coil and, of necessity, requires a capacitance to complete the circuit. The answer is known as top loading using a "capacitance hat" consisting of either a large disc, a number of horizontal wires in a spoke arrangement or other bizarre methods.

So we have one method of increasing the efficiency, so what other means can we use? Lets look at the ground loss. If we look at this area as the current return path, then, if we provide a large surface instead of a multiple number of wires, we can accomplish the same thing. I found an answer in a prod-

B is LOWER EMT SECTION AT BOTTOM OF MAST
B' is TOP EMT SECTION AT MAST TOP





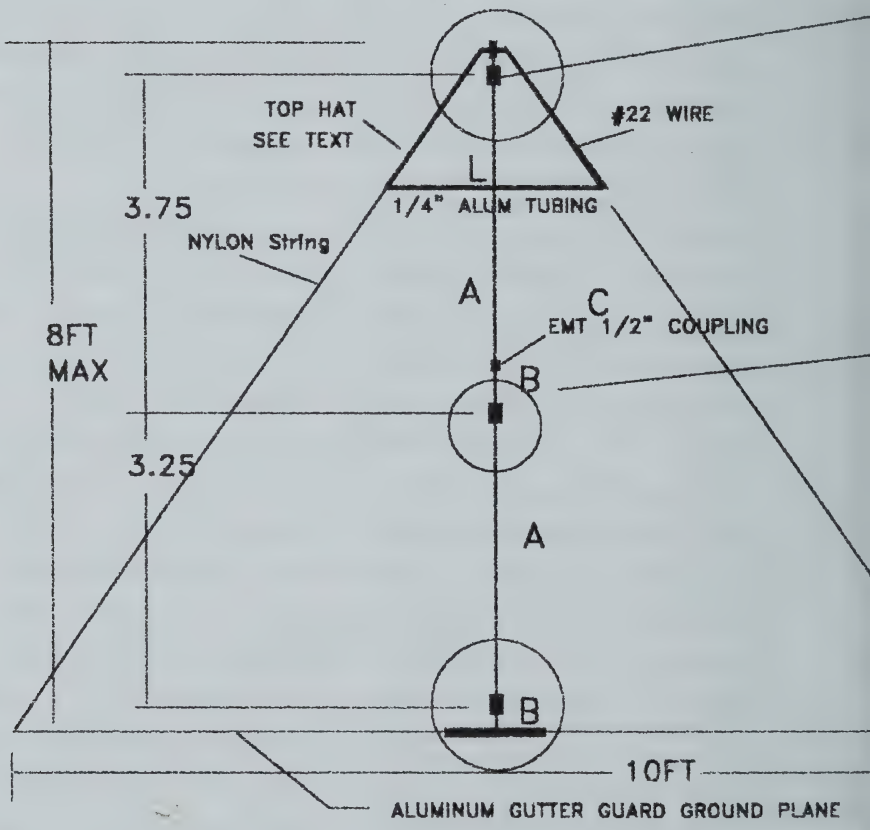
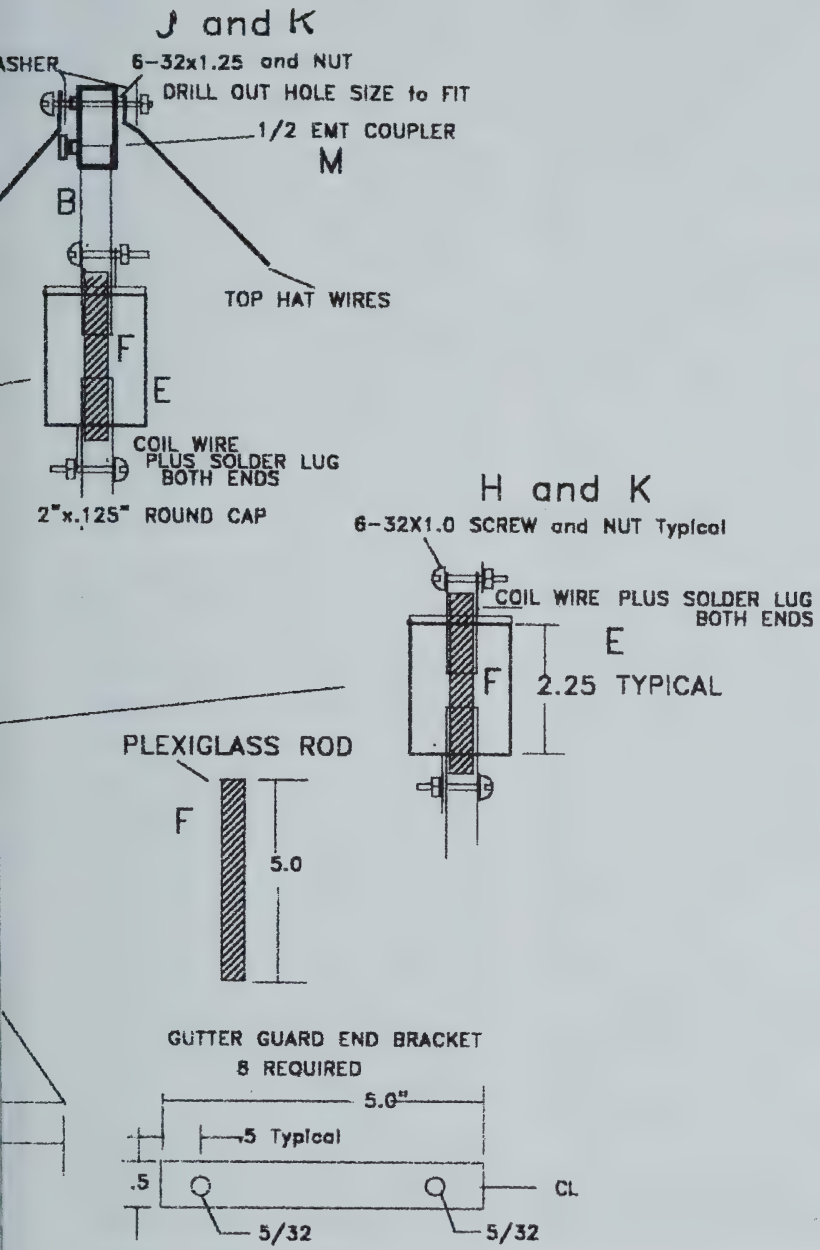


FIG 1

FIG 2


J and K
ASHER
6-32x1.25 and NUT
DRILL OUT HOLE SIZE to FIT
1/2 EMT COUPLER
M
B
TOP HAT WIRES
F
E
COIL WIRE
PLUS SOLDER LUG
BOTH ENDS
2"x.125" ROUND CAP
H and K
6-32X1.0 SCREW and NUT Typical
COIL WIRE PLUS SOLDER LUG
BOTH ENDS
E
F
2.25 TYPICAL
PLEXIGLASS ROD
F
5.0
GUTTER GUARD END BRACKET
8 REQUIRED
5.0"
.5 Typical
.5
CL
5/32
5/32

uct supplied by hardware stores that is used for covering rain gutters to keep out leaves. The material is an aluminum mesh 6 inches in width in a roll 20 feet long. Results using this material proved very effective as I will show later. SEE TABLE 1 I used 4 lengths 5 ft long forming a cross around the base of the antenna. Another loss source is matching this antennas resistance to the transmission line. (One to ten ohms for short antennas vs 50 ohms the transmission line impedance). There are several methods that can be used. One, keep the transmission line very short, but this probably is not very practical and still requires a matching network at the transmitter. Two, provide a matching network at the base of the antenna. (5) I looked at these various methods of coil locations and decided that it might produce a better antenna if all three of these methods were used. So this was the basis of the vertical I built. The antenna has a base coil with a number of turns with a tap to provide matching to the 50 ohm coax. The mid coil is about 1/2 up from the base and at the top is located an additional coil. The overall height of the antenna is 8 feet. So what to do about the top loading? The top coil requires a capacitance to make it effective. I decided to use part of the four guy lines (note I said lines not wires. I used nylon string for the lines.)

The upper 2 foot part of the guy line is actually wire used as part of the capacitance hat. The hat is completed by using a ring made from 1/4 aluminum tubing tied to the wires. Since the antenna is top heavy, guy lines are necessary to keep it erect. See FIG 1 and 2

Prior to assembling the antenna, I made an educated guess as to the inductances required for each position. I decided to put on more turns than necessary because it is easier to remove than to add turns. As I was progressing on this antenna, I thought why not have this antenna work on 30 as well as 40 meters. This has been accomplished by shorting out the center coil. The top hat and coil produces resonance at 30 M. See FIG 4 for 30M matching.

DATA on the 8 FOOT VERTICAL

It was important to have some sort of reference antenna to compare the short verticals for signal strength differences. (I made two verticals, one center is plus top loading and one base loaded). I made two coils for the base loaded antenna to see what effect a high Q coil vs a low Q coil would have on the efficiency. I used a 1/2 wave dipole at a 15 foot height as the reference. Although this was not considered to be a good height it was at the same level as the verticals and could be a typical height if used in a field operation.

A number of stations gave reports on the various antennas and in all cases the center loaded antenna (CLA) was equivalent or bet-

ter than the dipole and the base loaded was about 2S units lower. Instantaneous switching from one antenna to the other reduced the probability of atmospheric changes that would effect the accuracy of data. In some cases, the land line was used to relay the information so there was no time lapse from one position to another. It was difficult to determine absolute differences due to the signals fading. The peak readings were used.

The best DX to date is Monroe, Louisiana with an S4 reading while running 20 watts. I have also worked Colorado, Washington, Nevada and Mexico with good reports. All better than or equal to S7 with 20 watts except Louisiana.

The use of the wire mesh ground plane indicated a higher level of efficiency than the use of wires. This information was obtained by the higher SWR reading without using a matching section at the base of the antenna. The higher the SWR reading indicated the lower loss in the overall system. One can use this method to determine any changes on design to determine whether the efficiency has been modified. Of course, a base matching section must be used to obtain the benefits of the improved efficiency. (I used a MFJ antenna analyzer to make SWR measurements. Measurements were taken at the base of the antennas.) Based on other data that indicated the radiation resistance of these types of verticals with a height of 8 feet at 7MHz, I used the value of 2 ohms for the base loaded antenna and conservative 6 ohms for the center plus top loaded system. A value of 4 is used for a center loaded only antenna with out top loading. The calculated efficiency was approximately 8% for the base loaded antenna and approximately 30% for the centerloaded plus top loading unit.

The bandwidth, to where the SWR was greater than 2.0, was about 700kHz for the center loaded antenna and about 500 kHz for the base loaded system.

EFFICIENCY CHECKING

If you want to check the efficiency of the antenna you must disconnect the matching transformer and connect the 50 ohm line center conductor directly to the base of the antenna rod. Now read the SWR. It will not be at the 7MHz point but higher and will read at least 2 or above. The higher the better. Take this value and divide it into 50 which gives you the Rt value. Divide the Rr by this value and multiply by 100 to give the percentage efficiency.

ANTENNA RESULTS

(No tests have been made as yet as to its performance on 30 meters)

DATA TAKEN ON THE ANTENNA

Various configurations were made on the antenna during its development. The efficiencies for

these configurations are tabulated in Table 1

Other interesting data that was found

1: lengthening the ground plane using the 5" aluminum wire screen to twice the length had no appreciable effect on the efficiency. The same was true for the wire grounds.

2: the signal strength of received signals were about 2 S units higher on the CLA. However, signals coming from long distances were about the same.

3: for proper matching of the BLA, I used a variable capacitor to provide a 1:1 match. It was approximately 300pF connected from the feed point to ground.

4: the supposed higher Q coil for the BLA did not increase the efficiency as much as I expected. This was probably due to the denominate effect of the ground loss as compared to the improvement in the reduction of the coil loss.

5: wire type of ground plane was not as effective as the 5" mesh screen. However, the 8 wires were almost as effective.

6: going from 4 wires to 8 on the BLA gave approximately 50% improvement in the efficiency going from 6 to 9%.

7: going from 4 to 8 wires on the CLA gave only a small improvement. From 17 to 23% when no screen was used.

CONCLUSIONS

1: The CLA antenna gave a better performance than the base loaded antenna, however the extra work in its construction may not be considered enough gain (1 to 2 S units) to implement the system. For those who like to experiment with antennas, it might be worthwhile to see if they can improve on the system.

2: A short vertical can produce good results if you have a good ground system. The ground system does not need to be long (approximately the height of the antenna in length) but the number of wires will improve its efficiency up to a certain point. There is a point of diminishing returns.

3:Improving the Q of the coil of the base loaded antenna makes little change due to the denominate loss in the ground system and the low radiation resistance.

4: An antenna matching network at the base of the antenna is a must if the transmission line is long (greater than 1/16 wave length) to achieve maximum efficiency. If less, the matching can be done at the transmitter.

For those who have a limited space for a 40/30 meter antenna, this could be an ideal solution. It only takes up a floor space of 25 sq ft (5x5).

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2.Radial Systems for Ground

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3.Losses in Air coils at Radio Frequencies, Terman Radio Engineer's Handbook page 74
4.Evolution of the Short Top Loaded Vertical, C Michaels W7XC page 86 ARRL Vertical Antenna Classics, First edition Also March 1990 QST
5: ARRL Handbook chapter 33 Sixty six edition

I wish to thank Dave Meacham W6EMD for his perusal and comments in helping write this article. Also to Floyd Becker W6RJY, Santa Rosa, for giving the listening and signal reports on the various antennas and Jack Cash, W6ORR, who gave me signal reports from his location about a 1 mile from my QTH.

I would appreciate any comments you may have on this subject. Jim Pepper W6QIF@ i.x.netcom.com

CONSTRUCTION DETAILS

The basic configuration of the whole antenna is shown in Fig 1 and Table 2. Three coils are to be constructed, one for the base matching, one for the center coil and one for the top loading coil. All three are wound on 2"D by 3"L with a wall thickness of 0.125 inches plexiglass tubing (available from TAP plastics). The core for the coil forms is made from 5/8d plexiglass solid rod.

The mast material is 1/2 inch EMT metallic tubing which has an inside diameter of .622 or slightly smaller than the rod size of.625. I found by using a 1/2 inch round file that the opening could be enlarged sufficiently to take the slightly larger diameter of the rod. It should be a snug but not too tight because you may want to remove it during some construction operation. The rod extends inside the EMT about 1.5 inches. The holes drilled on the coil forms are identical for each coil. The wire is fed through a hole in the cap and attached to the screw on the EMT using a solder lug See Fig 2 and 3. The other end of the coil attaches to the lower section of the EMT. The upper part of the EMT, from the center coil to the top loading section, is broken in two sections to allow easy transportation of the unit. An EMT coupling is used to attach the two section together.

TOP HAT

The top hat is made from a 10 ft length of 1/4" aluminum tubing. Mark off 4 points 30 inches apart to indicate where the wires will connect to the tubing. Form the tubing into a 3 foot diameter circle. The open ends are connected together using a 1/4x1/4 compression union. (ACE hardware #43008) The tubing is connected to the antenna mast by 4 #22AWG enamel wires. Each leg is 2 ft long but is made from one piece that is 4 ft long. The center point of this

wire has its enamel removed. This center is later wrapped around the screw located on the EMT section at the top of the antenna. I used an EMT coupler for this purpose to attach the hat to the top of the mast. See FIG 2 The wires are attached to the aluminum tubing by homebrew aluminum straps bent around the tubing and held in place by a nut and screw. This completes the making of the hat. From these four points the nylon guy lines are attached. I used a product used on leashes that clamp on to a dog collar which allows a quick disconnect.

WINDING the COILS See Fig 2 and 3

The each coil is wound with ten turns of #18 enamel coated wire. 10 Feet per coil. A pig tail is left on each end of the coil of 1.5 inches to allow attaching to the mast. I used a solder lug for this purpose. Mount the solder lugs on the mast and then atttach the coil leads centering the coil in the middle of the opening of the plexiglass insulator.

I found the best way to wind the coils is put the wire thru the hole on the coil form and attach the other end of the wire to some non movable object. Pull the wire taunt and start winding the coil. Wind the coil such that it covers the total form with proper spacing. Put the other end thru the other end of the form.

I used scotch tape to hold the wire spacing temporarily in place. Using DUCO Cement (Tm), I secured each wire in place. I did only a few wires at a time. I also left the last 3 wires un cemented to allow further adjustment for proper frequency range.

It is possible to move the wire spacing before the cement completely dries to correct for bad spacing. It doesn't have to be perfect it just makes a nicer looking construction.

MOUNTING the COILS See Fig 2 and 3

The coils are mounted using a plexiglass cap obtained from TAP Plastics. It is a 2" diameter by 1/16 piece that will be cemented to one end of the coil with DUCO cement. The cap is modified by drilling a 0.7 dia hole at its center. I used a pilot hole of 3/8" which was large enough to allow a tapered reamer to enlarge the hole. The hole should be a tight fit over the EMT which is 0.706 in diameter. An additional hole for the wire feed thru is required as shown in Fig 3.

The wired coil form, with wires coming out top and bottom, is now ready to mount to the EMT mast. The two ends have the enamel removed and attached to a solder lug. The coils are then placed on the mast and attached as shown in Fig 2 using 6©32 screws.

BASE COIL Modification See Fig 4

To allow proper matching to the 50 ohm coax, a tap is made on the base coil. The tap is located

two turns from the bottom end for the coax. The clip lead for the center of the coax connector is connected to this point. In addition, to properly match the 30 meter operation, an additional wire is connected to a tap per Fig 4. This tap is 4 turns up from the bottom. This wire is connected to the top of the base coil for 30 meter operation.

GROUND SYSTEM

The following method is how I connected the base of the antenna to the ground system. It is a suggested method and you can modifiy it to fit your requirements. I mounted the mast onto a 6"x 12"x1/4" aluminum plate using a 1/ 2" EMT box connector. This allows the antenna to be removed from the plate. The SO239 connector is mounted to the plate with screws using a L shaped bracket.

A wire from the SO239 center pin attachs to the base coil by an alligator clip on the end of the wire. This allows the antenna to be removed from the base without unscrewing the SO239 from the plate. The 30M connector wire also uses an alligator clip for easy 30M modification.

The 6" wire mesh is attached to the aluminum plate by 1"x6"x1/ 8" bar stock which is screwed to the plate. The wire mesh is placed under the bar stock and then held in place by the bars. For transportation of the antenna, the ground wire mesh can be rolled up and held in the roll position by clothes pins while still attached to the plate.

30 METER OPERATION (If you are only interested in 40M operation skip this next step.)

The 30 meter antenna is the first to be adjusted for proper frequency operation. The antenna can be converted to 30 M by shorting out the center loading coil. See Fig 4 for the proper load matching connection for this band. Using the MFJ analyzer at the base of the antenna, I tuned for minimum SWR. If the frequency was too low, some turns must be removed from the top coil. If you left some turns on this coil without being cemented down, you can move them further apart to see if this gets you into the band. If it is on the high side, try moving the turns together. If this isn't sufficient, I attached a small length clip lead to the 1/4"top hat tubing (any spot) and see its effect. A one foot clip lead will change the frequency by 150kHz. Trim to give proper frequency.

40 METER OPERATION

Next remove the jumper from the center coil and set the signal source to the portion of the 40 meter band where you normally operate. Re set the matching transformer connection for 40 M operation. Check the SWR at the desired frequency of operation. If the SWR is above 2, you will have to adjust the center coil windings. Locate where it drops down to 1:1 and make the corresponding adjustments. You should have left a few turns at the

top or bottom of the coil to make this adjustment.

The antenna is now ready for on the air testing.

FIG 1

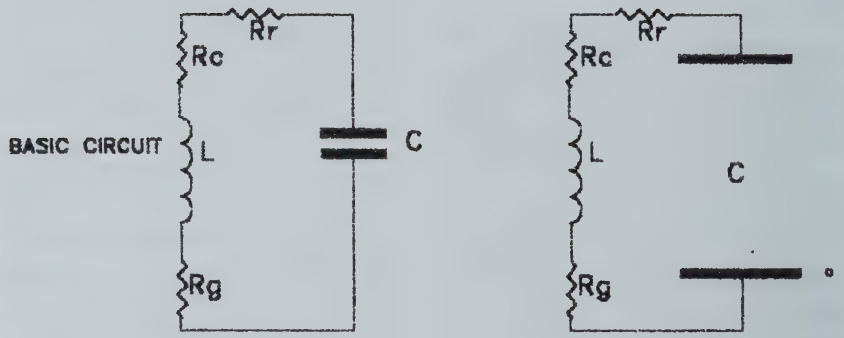


FIG 3

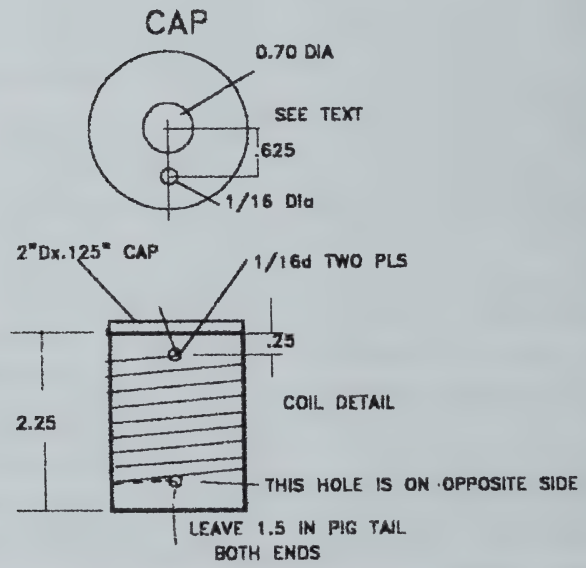
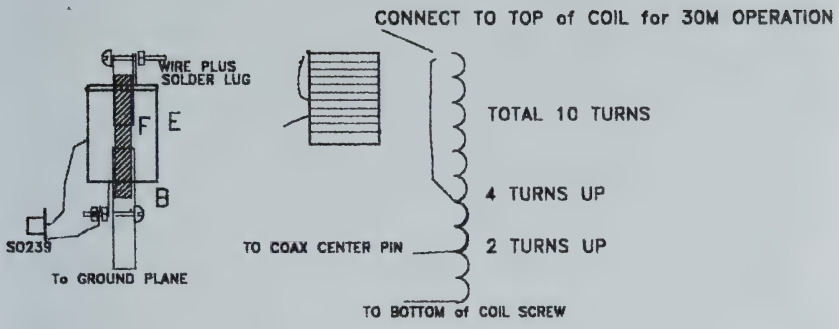


FIG 4



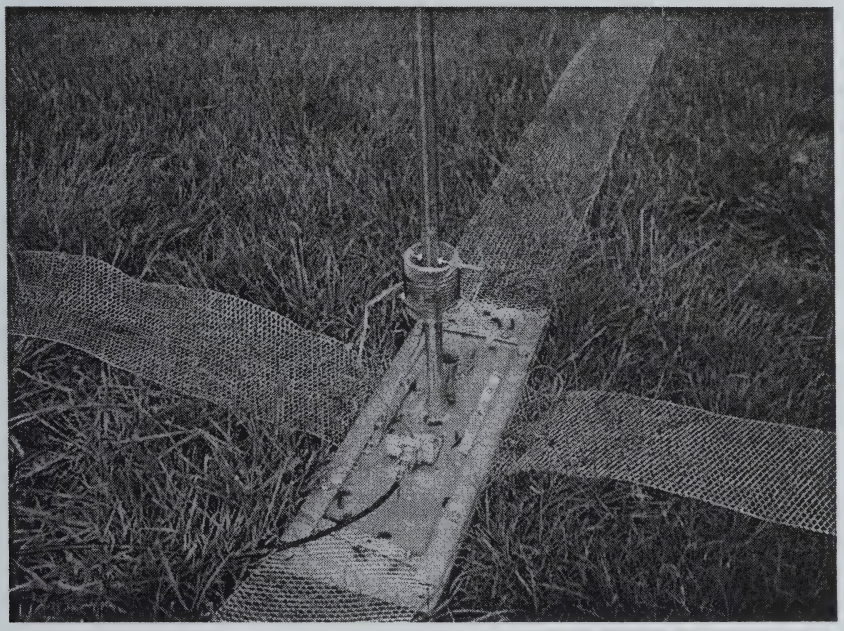
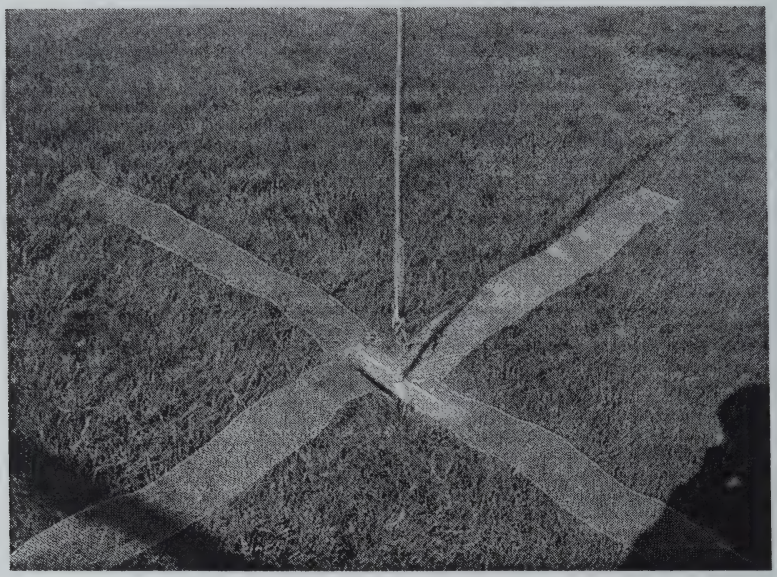


Photo 1 Base Plate



Base Loaded Antenna

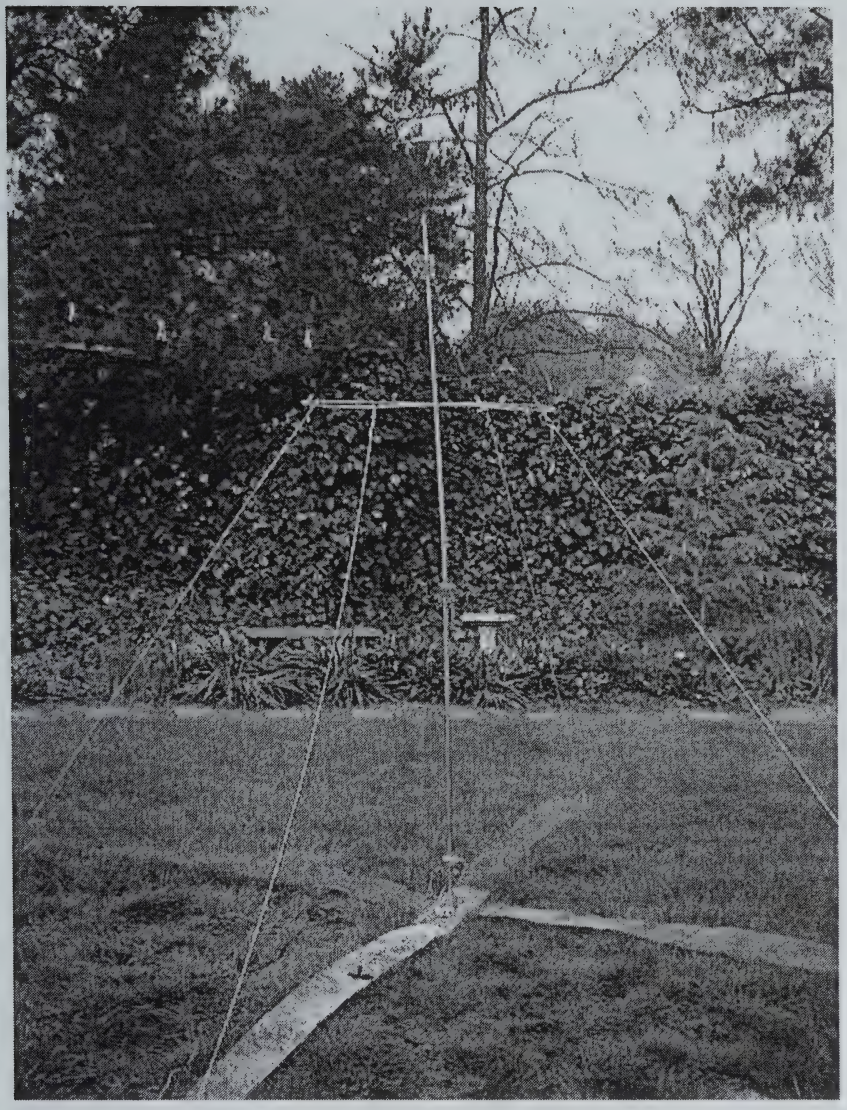
TABLE 1

ANTENNA EFFICIENCY BASE LOADED	1" DIA. COIL EFF. % *	3" DIA. COIL EFF % *
4 #22 AWG 8 FT. LONG	6	6
8 #22 AWG 8 FT. LONG	8	8
4 5' SCREEN 5 FT. LONG	11	11
8 #22 WIRE + 4 SCREENS	12	12

* RADIATION RESISTIANCE 2 OHMS FOR BASE LOADED ANTENNA 8 FEET LONG @ 7 MHz.

CENTER + TOPLOADED	EFF. %
4 #22 AWG 8 FT. LONG	17
8 #22 AWG 8 FT. LONG	23
4 5' SCREEN 5 FT. LONG	31
8 #22 WIRE + 4 SCREENS	32

* RADIATION RESISTIANCE 6 OHMS FOR CENTER-TOP LOADED ANTENNA 8 FEET LONG @ 7 MHz.



Center Loaded Antenna

TABLE 2

A	2 LENGTHS 1/2" EMT 3.25FT L
B	3 LENGTHS 1/2" EMT 6" L
C	1 PC 1/2 EMT COUPLER
D	3PCS 2"Dx1/16 PLEXIGLASS
E	2Dx2.25L PLEXIGLASS TUBING 1/8" WALL TH 3 PCS
F	3PCS .625DIA PLEXIGLASS ROD 5" L
G	8PCS 6-32 FLAT WASHERS
H	6PCS 6-32 MACHINE SCREW 1.0L
J	6-32 MACHINE SCREW 1.25L
K	7PCS 6-32 NUTS
L	10FT Aluminum 1/4" TUBING
M	1 PC 1/2 EMT COUPLER
N	40 FT #18 E.C COPPER WIRE
O	5"x20FT Aluminum GUTTER SCREEN ACE HARDWARE PRODUCT
P	1/2"x 1/16" AL FLAT BAR

Note: Only the lower section A has holes on both ends.

USING AN OSCILLOSCOPE AND LOAD RESISTOR TO ESTIMATE R-F POWER

by George Baker, W5YR

Measuring the output power of a transmitter, especially a QRP rig, can be difficult task. Conventional "wattmeters" usually lack accuracy at power levels of 5 watts and below. Even the popular Bird 43 goes down only to 50 watts full scale with an accuracy of +/- 2.5 watts. R-F power meters from major test equipment manufacturers are prohibitively expensive overkill for most amateur applications. Similarly, r-f voltmeters that work up to several hundred Megahertz are available and, while very convenient to use, are costly, present an ongoing calibration problem, and are usually more than is required for the purpose.

The QRPer who possesses an oscilloscope, or access to one, and a good 50 ohm load resistor has the basic equipment required to make useful estimates of QRP transmitter power output. The scope should have an upper frequency response of at least twice the operating frequency and a means for calibrating the vertical input channel. Most scopes provide an internal calibration signal that is adequate for the purpose. Load resistors can range from small non-inductive resistors of adequate power rating to dedicated artificial loads such as the venerable Heathkit Cantenna and its modern-day counterparts.

Following is a brief description of the procedure one would use to measure the output power from a transmitter using a scope and load resistor. A numerical example is included to summarize and illustrate the procedure.

PROCEDURE

First, make sure that the output signal from the transmitter is a sine wave - no harmonics or waveform irregularities to complicate things. No modulation, either - just a steady continuous sine wave signal with no peak amplitude changes with time.

Second, make sure that the signal is present and constant long enough to get it synched up on a scope and the amplitude observed. Note that the scope must have a high enough frequency response to show the transmitter signal accurately. Don't try to measure a 10 meter signal with a 5 MHz scope. To avoid heating the load resistor and causing its resistance to change, do not apply power for more than several seconds at a time.

Third, assume that the scope vertical amplifier is properly calibrated. Most scopes have a cali-

brator signal brought out on the front panel. Use that to verify the control setting. If the probe is either X1 or X10, take that into account when figuring the vertical gain control setting in volts per division of the scope graticule - that graph on the CRT face.

With the signal present on the screen and the gain set for a convenient signal amplitude - try for about two-thirds of the screen height - measure the peak to peak amplitude of the sine wave in scope graph division and convert this to volts. Call this Vp-p.

Divide this by two to get the peak voltage Vp, and then multiply the peak voltage Vp by 0.707 to get the rms voltage Vrms.

Square Vrms and divide by the resistance of the load across which the voltage is being measured.

The result is the power (in watts) being delivered to the load resistance (in ohms) with the observed voltage (in r-f volts) across it.

A formula would look like:

P = (Vrms)^2/R.

EXAMPLE

First, get the scope all set up and calibrate the vertical channel, etc. for five volts per vertical division. That means that the distance between the horizontal lines on the graph on the face of the scope represents a voltage change of 5 volts. Since the load resistance is fairly low, using a "X1" probe or a probe with a X1 setting saves a little mental arithmetic and won't load the circuit and affect the results.

Next, connect the transmitter output to the load resistance which has been previously measured and found to be 47 ohms. Use the shortest possible connection to minimize the errors introduced by the feedline, since if the load resistance doesn't match the characteristic impedance of the feedline, and provide the required transmitter load, there will be reflections which can change the scope waveform. This may sound like a minor effect, but it can have a major impact on accuracy, regardless of the method used.

Make sure that the resistor can dissipate the transmitter power for at least several seconds without overheating and changing resistance while you read the scope pattern. Keep the transmitter on no longer than absolutely necessary to read the pattern. Otherwise, the resistor will heat up and change its value. This can seriously affect the accuracy of the measurement by this or any other procedure.

With the transmitter on, quickly but carefully measure the height on the scope graph from a negative peak to a positive peak. This might be something like 6.8 divisions on the scope graph. Knowing that we have the scope set for 5 volts/division, we calculate that Vpp, the peak-to-peak voltage of our waveform, is 6.8 divisions times 5 volts per division or 34 volts.

Now, we have the basic information we need to estimate transmitter output power: 34 volts peak-to-peak across 47 ohms.

Divide Vpp by 2 to get Vp = 17 volts. Multiply Vp by 0.707 to get the Vrms = 12 volts. Square Vrms to get 144 and divide by the resistance value of 47 ohms to get 3.064 watts. Since there are several sources of error involved, we estimate the power at an even 3 watts.

Assuming the scope is properly calibrated and the pattern read with accuracy, one of the major sources of error is the resistor value changing with temperature and the effects of a long feedline between the transmitter and the load resistor. For example, if the resistance increased with heat to 50 ohms instead of the measured 47 ohms, the resulting actual power would be 2.88 watts instead of the 3 watts calculated by the formula. This difference is an error of four percent, which illustrates how important it is to use a known resistance and ensure that it does not heat up.

If these precautions are observed, this method can yield surprisingly accurate measurements in a power range where even sophisticated equipment can have problems.

"SPaddle" – A Lightweight Vertical Paddle

'Seab' Lyon, AA1MY

The vertical paddle or "SPaddle" was designed for the ARS "Spartan Sprint", where station weight is a concern. This particular model weighs about 1/2 oz. and was made to fit and be taped between screw heads under an Altoids box, or to a logging clipboard. The paddle is operated with one's hand resting on the box or the base plate, providing single-handed stability. In fact, it is designed for use outside and with gloves, where cold fingers cause errors. It is not intended to be the perfect paddle for comfy indoor use.

"SPaddle" is made from .032" thick, double sided, fiberglass printed circuit board. It could be made from more common .062 stock but would weigh more and the action will be stiffer. Notching at the "contact land" will give it a lighter touch. SPaddle can be made to meet any circumstance as dimensions are completely non-critical.

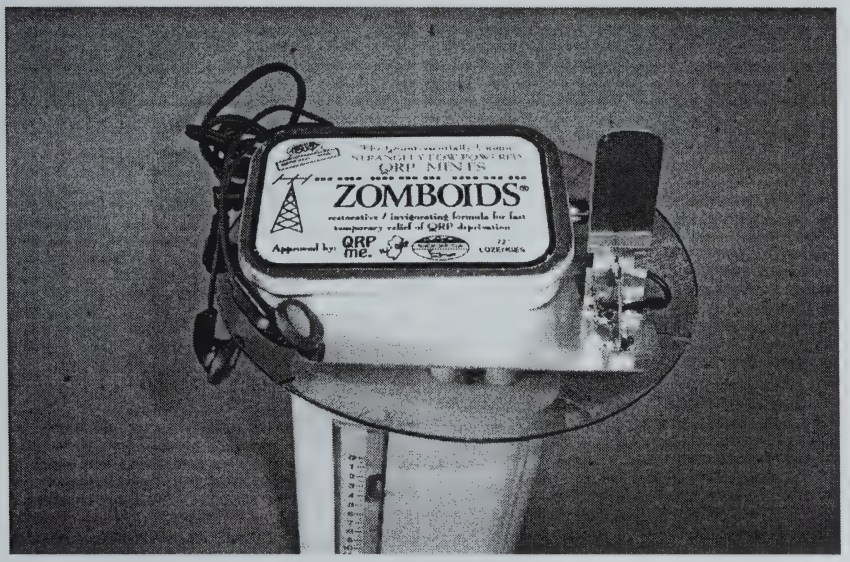
Contacts are made of #14 copper wire, soldered to the contact arms, and trimmed to fit before attaching the contact arms. File or grind a flat on the contact face. Contact spacing is adjusted by heating the solder and nudging the wire, using a thin sheet of paper as a gap set. An adjustable but weightier alternative would be to turn the contact arms parallel to the lever, solder a nut over a hole in each arm and use a screw and locking nut. (similar to the horizontal design in QST a while back) Copper is removed from the contact land by cutting through the copper (only) with an Exacto knife, heating the strip with a hot solder tip and peeling it off. (thanks, KD1JV)

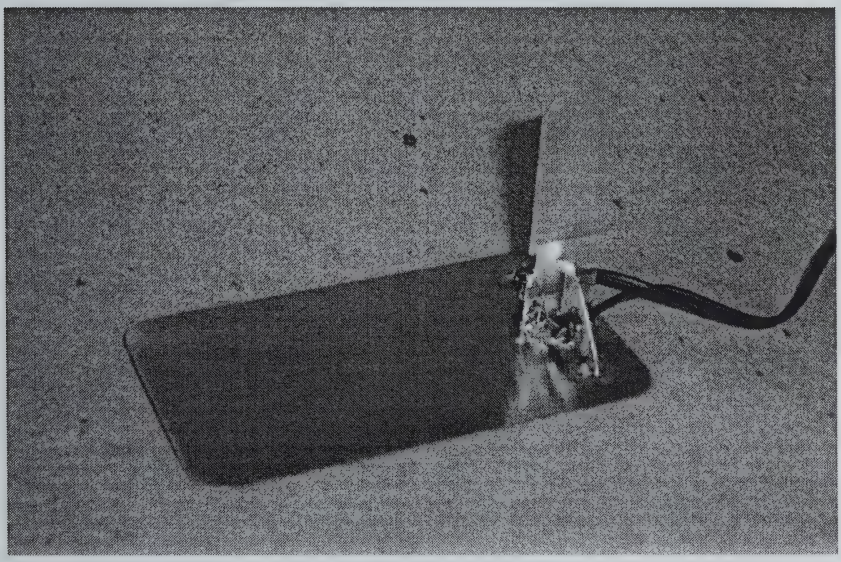
The photo shows how SPaddle is built, and the cutting layout provides nominal dimensions. A "nibbler" was used to notch the paddle arm at the "contact land" to increase flexibility. A round file would work as well. The wire and plug was happily liberated from a cheap pair of particularly painful stereo ear buds. Wires are passed through holes in the contact arms and knotted for strain relief.

That's about it except that I'd recommend masking the contact area and spraying the SPaddle with clear varnish to preserve the shiny copper. Clear packing tape works too, but it's more difficult to protect the whole thing. After taking time to fine tune and get the feel of SPaddle I've found it to be a good step toward the Spartan ideal. That, in combination with KD1JV's remarkable "A-T Sprint" transceiver, took first place in the Skinny Division for the April '03 Spartan Sprint with a station weight of 12.3 oz. Feel free to make im-

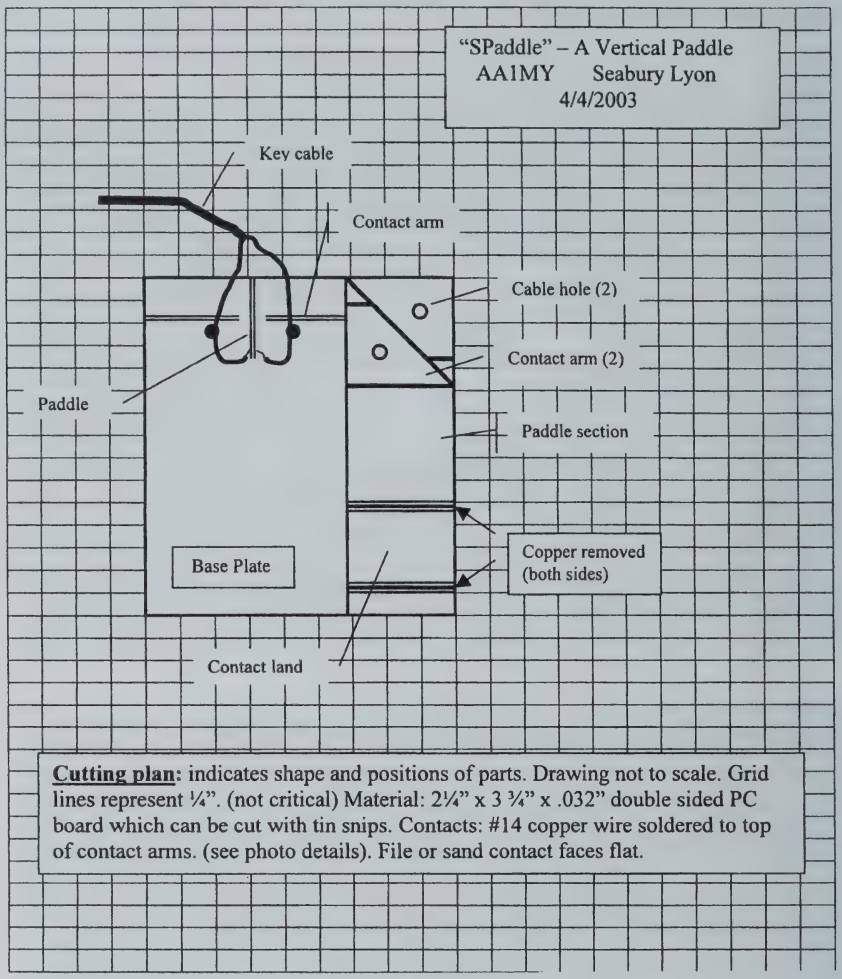
provements, and please don't forget to share them with us!

73, Seab,





Seabury Lyon AA1MY April 10, 2003



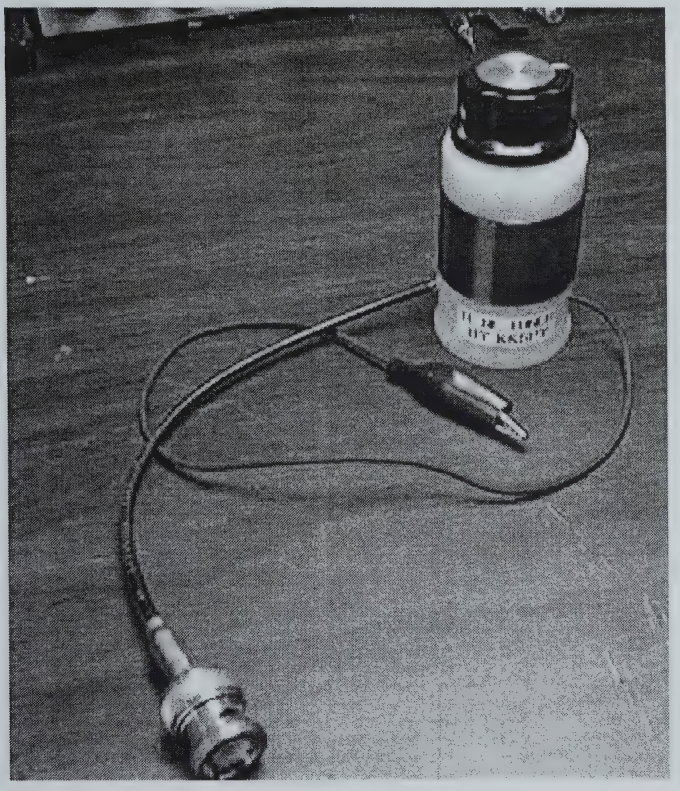
Cutting plan: indicates shape and positions of parts. Drawing not to scale. Grid lines represent ¼". (not critical) Material: 2¼" x 3 ¾" x .032" double sided PC board which can be cut with tin snips. Contacts: #14 copper wire soldered to top of contact arms. (see photo details). File or sand contact faces flat.

KK5PY's Te Ne Tuner

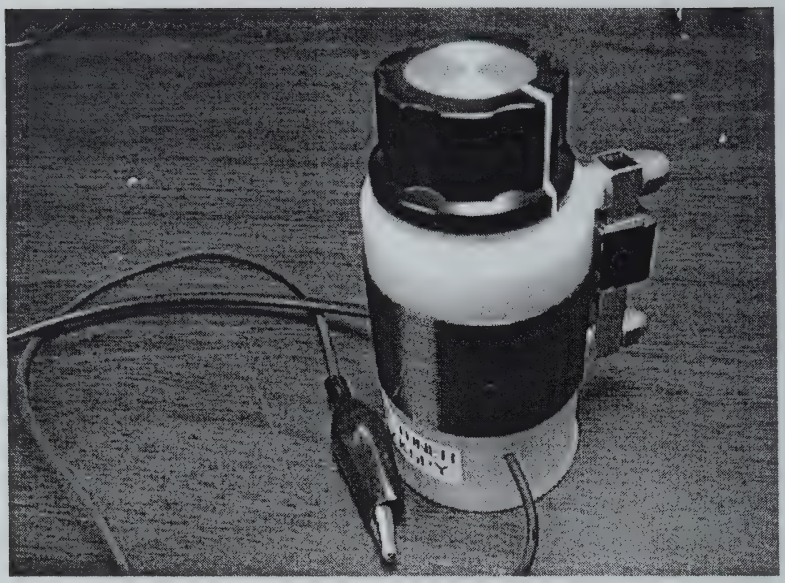
by Lew Pacely, N5ZE
lew@paceley.com

I'm immediately attracted to compact, innovative radio and accessory designs. While at Arkiecon Don, K5DW, (knowing my weakness for these things) brought me over to Dennis, KK5PY's table to see Dennis' latest wonder - the Te Ne Tuner. The Te Ne Tuner is basically a small L-network tuner (series L, shunt C) designed specifically to match end fed wires. End fed wires are among the easiest wire antennas to erect and use and Dennis has come up with an innovative little transmatch design to throw in your pack with your rig the next time you head for the hills.

Dennis has managed to squeeze an entire tuner into a plastic 35mm film can! On the top is knob to vary the capacitance of the polyvaricon inside the film can. The



The KK5PY TENE Tuner



The Inductor is tuned with a sliding contact.

The TENE Tuner "innards"

inductor is wound around the film can body and tuned with a sliding contact on a brass tubing rail. A wire with an alligator clip connects to the antenna. A short piece of RG-174 coax connects the tuner to the rig. Note that the BNC connector is NOT stock. I removed the stock RCA phono male and replaced it with a BNC male.

I use an end fed inverted L with a 33' RF ground as my main shack antenna. I connected the Te Ne Tuner and was surprised to be able to use this simple transmatch to tune every band but 15m to 1.4:1 SWR or less using my MFJ-259B. On 15m I couldn't do better than 2.3:1 SWR. But that's an amazing result for such a featherweight little transmatch!

The only disadvantage I found to Dennis' design is that hand capacitance significantly affected tuning at 20m and above on my antenna. To work around the hand capacitance detuning, I simply adjusted the slider and moved my hands away to observe the result of the change. I found I could get the tuning fairly close just by listening to the background noise in my receiver.

Also, while the sliding contact is insulated by a small plastic cover, the brass tubing and hardware is not insulated. It's not very hard to accidentally get your fingers to touch the brass hardware while tuning SO USE CAUTION AND AVOID RF BURNS!!

Disclaimer: I have no business relationship with Dennis, KK5PY, other than satisfied customer. The TENE Tuner can be ordered for $25 + $4 Shipping and handling from:

Dennis Foster, KK5PY
300 N. Maple
Commerce, OK 74339

Please make checks and money orders out to Dennis Foster, and it helps a bunch if you enclose a self addressed mailing label.

How to Build the NorCal Doublet Antenna

by Doug Hendricks, KI6DS---------

The NorCal Doublet Antenna came about due to my desire for a simple antenna that could be erected very fast, only needed one center support, and did not take up much storage room. Dave Gauding, NF0R, is a close friend of mine, and he had told me about a St. Louis Doublet, that used small wire for the radiators and computer cable for the feedline. I took his idea a step farther, and used computer cable for the whole antenna. Jim Duffey, KK6MC/5 and Dennis Foster, KK5PY, also contributed to the design.

Jim was the one who told me that if I made the legs 22 feet on a side that the antenna would have basically the same radiation patterns on all bands from 40 – 10 meters. This would be very handy to have for field operation, so I decided to use it.

Here is how to make the NorCal Doublet. You will need the following materials:

50 feet of 4 stranded computer cable
1 #0 Fishing Swivel
1 Cable tie
2 pieces of fishing cord

1. Take the computer cable, and strip the outer two conductors down 22 feet, leaving the two middle wires connected together.

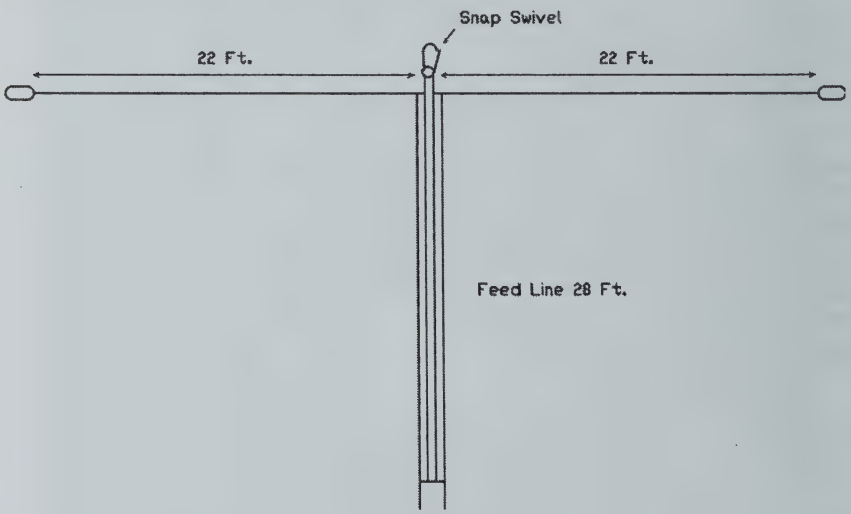


Fig. 1 Dimensions of the NorCal Doublet

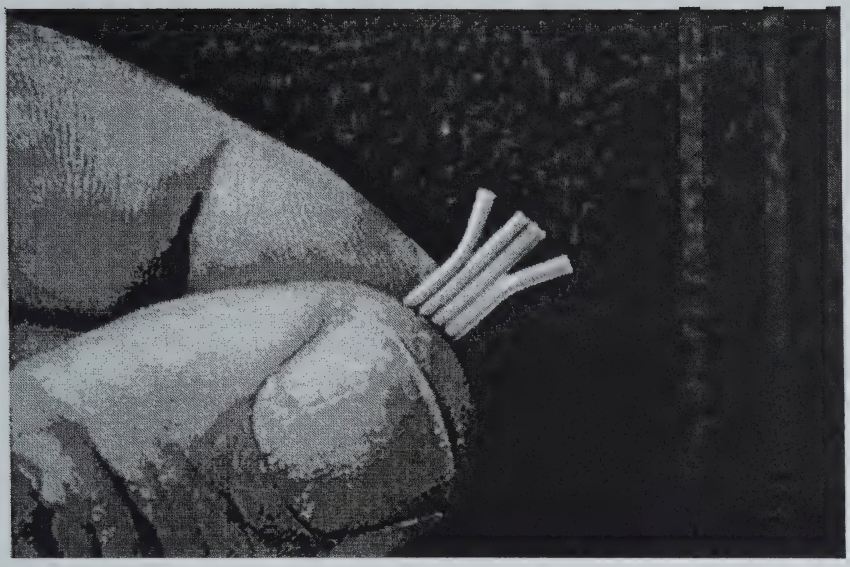


Fig. 2 Detail of starting to strip the 4 conductor computer cable.

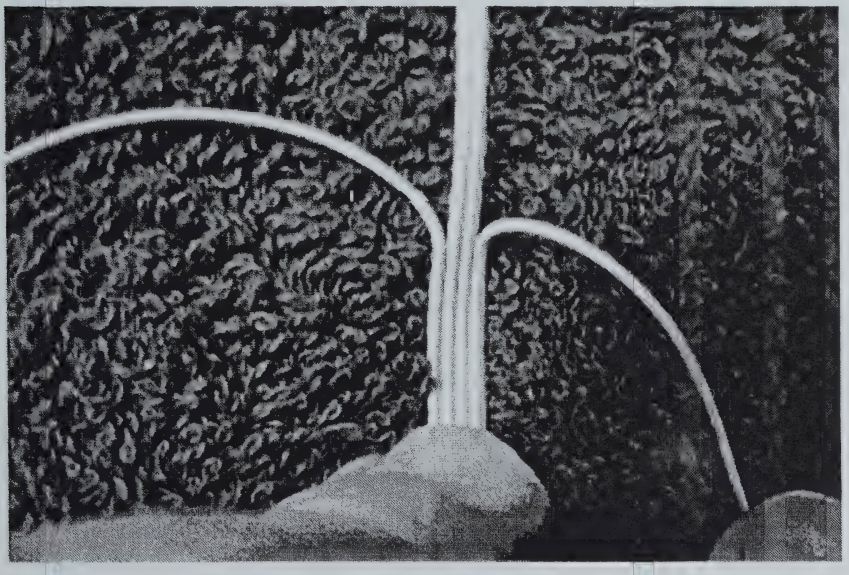


Fig. 3 Computer cable that has been stripped down 22 feet.

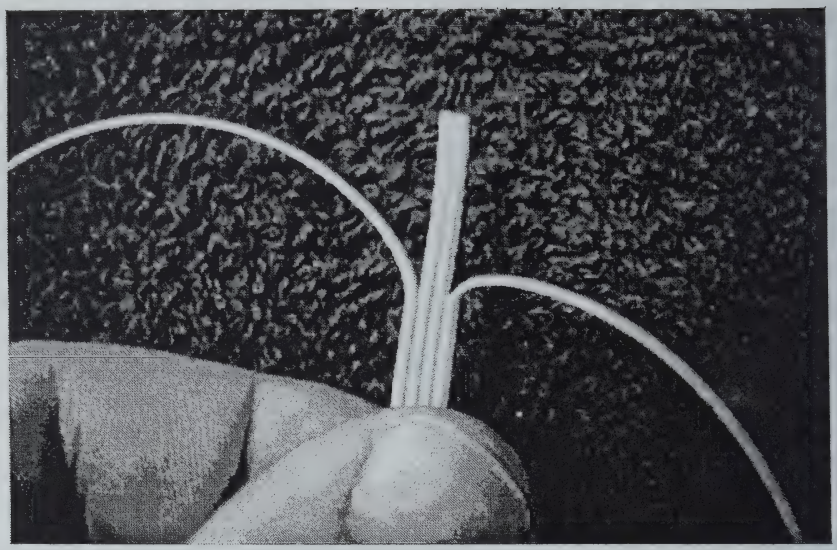


Fig. 4 Step 2. Cut the two middle wires off about 2" above the 22 foot mark where you stopped stripping the outer connectors.

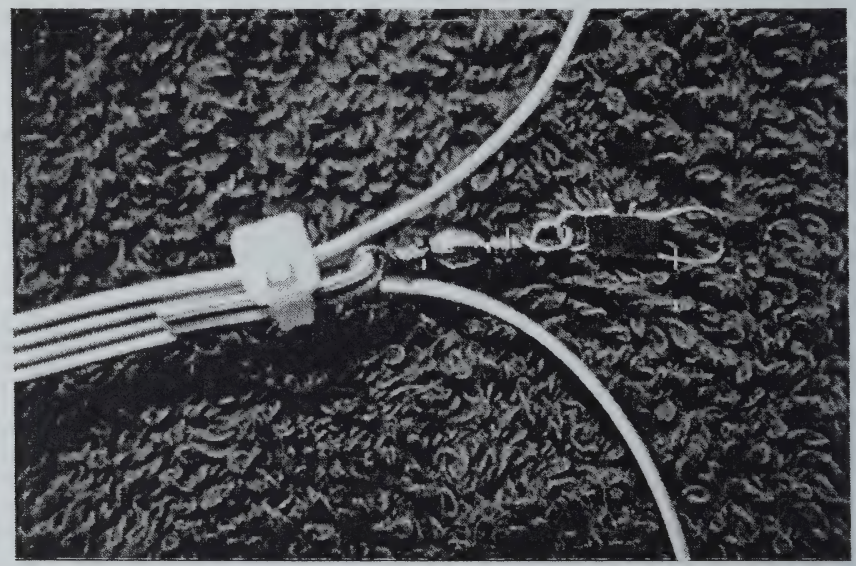


Fig. 5 Step 3. Loop the 2" piece of double strands over the eye of the fishing swivel. Step 4. Secure the whole thing by wrapping the tie wrap around the feedline and loop. (Dennis Foster showed me this idea)

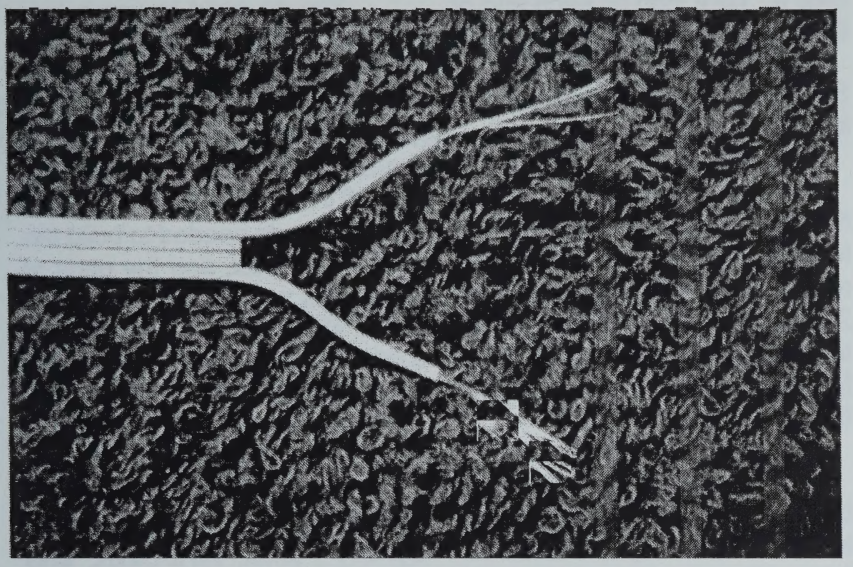


Fig. 6 Step 5. Use the remaining 28 feet of 4 conductor cable as the feedline. The outer two wires will be the feedline. Strip off about 1" of insulation on both outer connectors to hook to your NorCal BLT tuner.

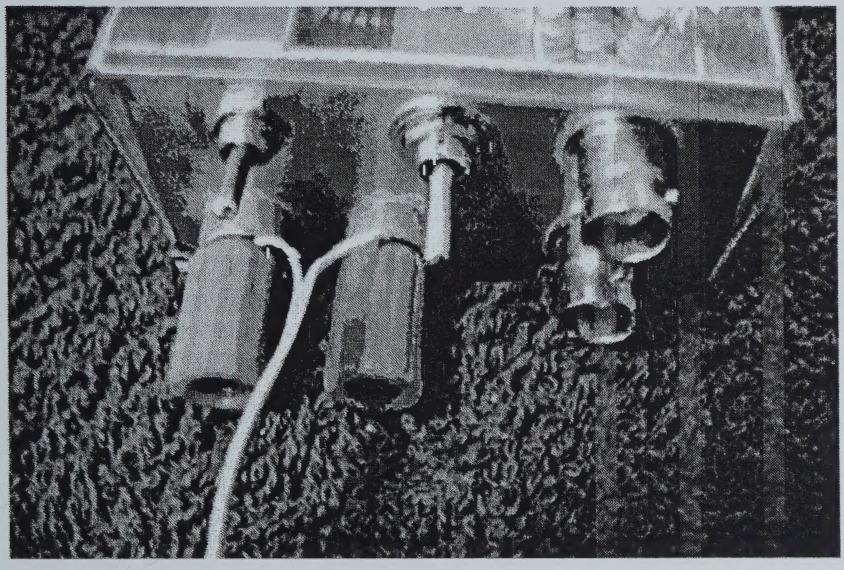


Fig. 7 NorCal Doublet Hooked to back of NorCal BLT Tuner.

Step 6. Tie a loop on each end of the two 22 foot wires.

Step 7. Tie the fishing cord to the loops.

To erect the antenna, clip the fishing swivel to the eye of the 20 foot fishing pole. Extend the pole and set it up. Stretch out the two 22 foot wires and tie off the strings to suitable supports. Connect the feedline to your tuner, and get on the air.

I have used the NorCal Doublet for years, and it is a good antenna that will let you make contacts. I have never not been able to make a contact with someone, somewhere. Is this a DX killer, no it isn't. It is a simple antenna designed to be supported by a telescoping fiberglass pole.

It is designed to be light, portable and simple to make and deploy. I have made several of them while giving a QRP talk to a forum, and everyone of them turned out just fine.

You do need to use a balanced line tuner with it though. An excellent one is the NorCal BLT, in fact, the NorCal Doublet was designed to be used with this very tuner. The BLT is available from me for $29 including shipping. You get all of the parts needed to build the tuner, a manual, and the parts to even build a case out of precut pc board material. You can see pictures and find more information on the NorCal Web Page at:

www.norcalqrp.com

This web page is maintained byJerry Parker, WA6OWR, who does a fantastic job for NorCal.

To order a tuner send a check or money order for $29 US funds only to:

Doug Hendricks
862 Frank Ave.
Dos Palos, CA 93620

Please make checks or money orders out to Doug Hendricks, not Norcal.

The NorCal Web Page

NorCal maintains a web page that has many late breaking announcements of interest to QRPers. Our web master is Jerry Parker, WA6OWR. Please check the web page at:

www.norcalqrp.com

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